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(54) Title of the invention: **Apparatus for radially expanding a tubular member**

(51) Int Cl⁷: E21B 43/10 33/14

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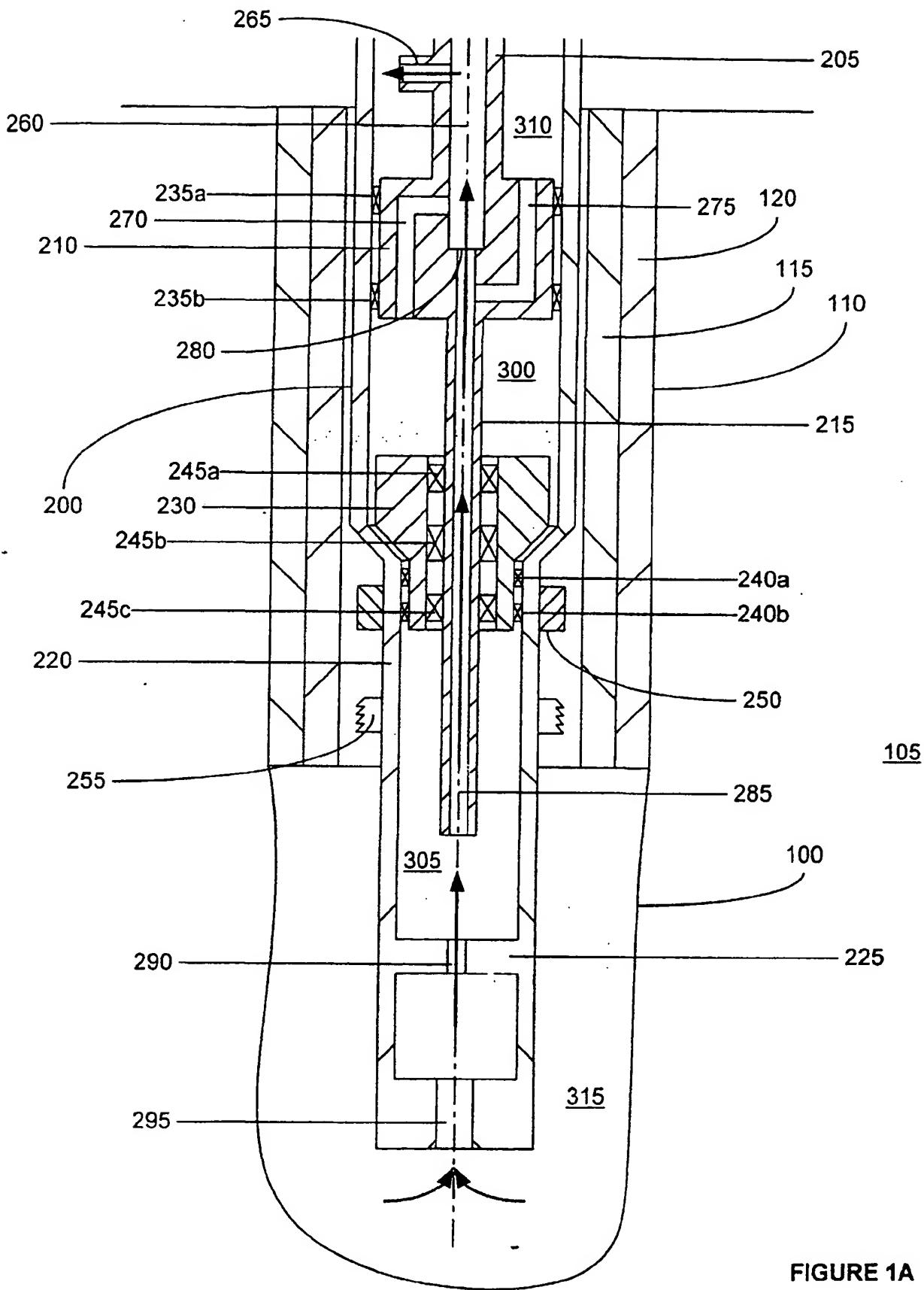
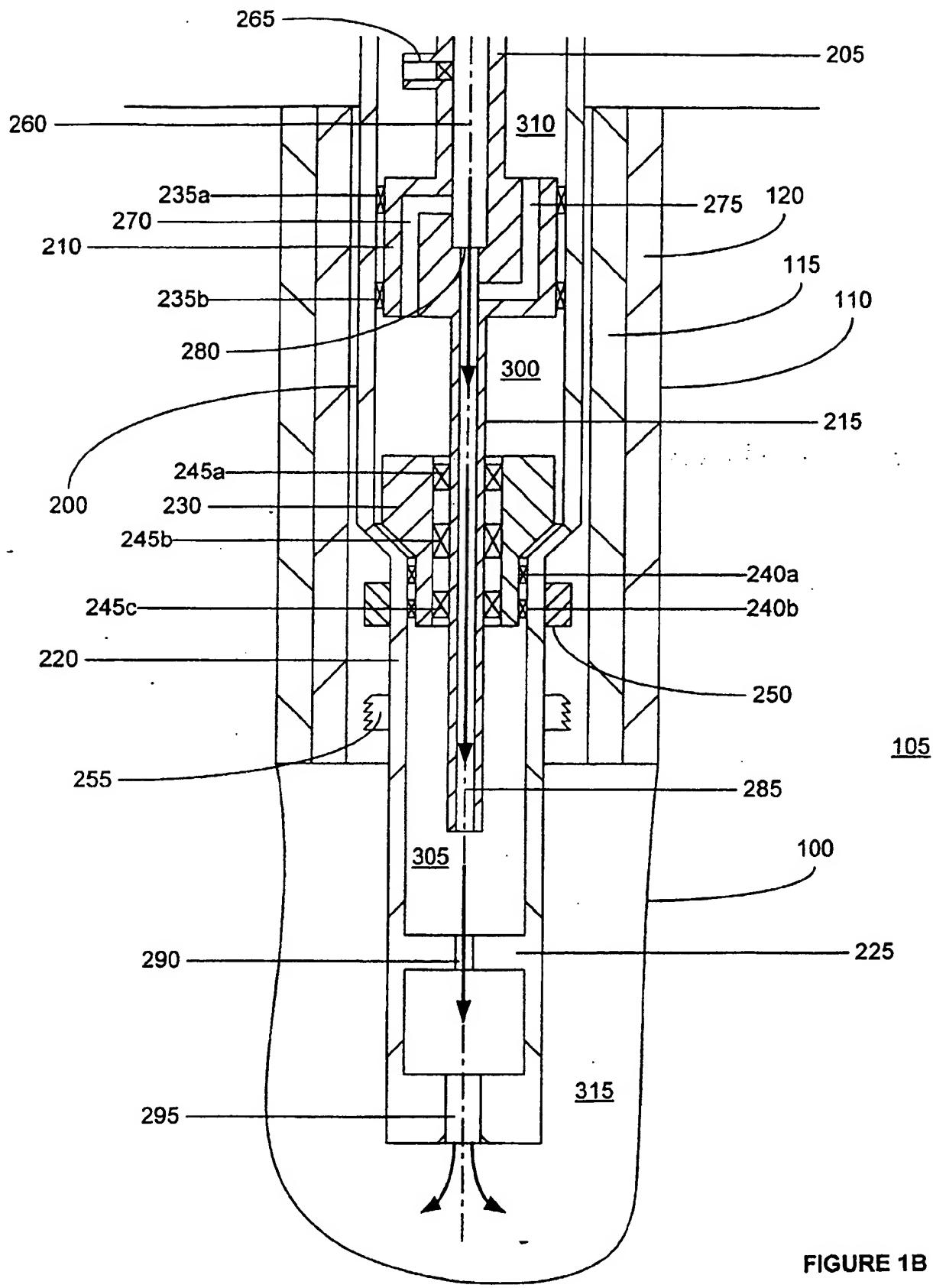


FIGURE 1A

**FIGURE 1B**

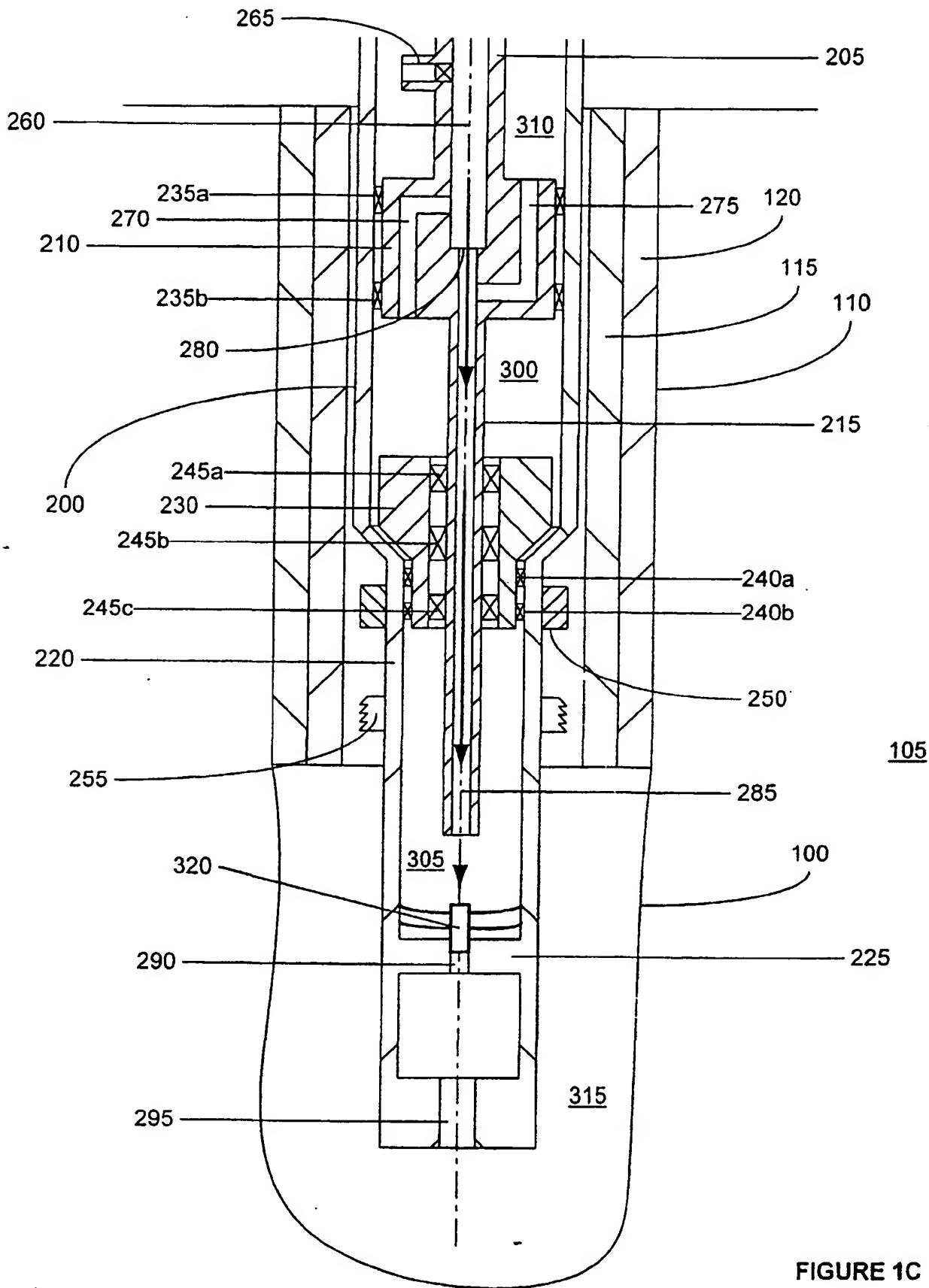


FIGURE 1C

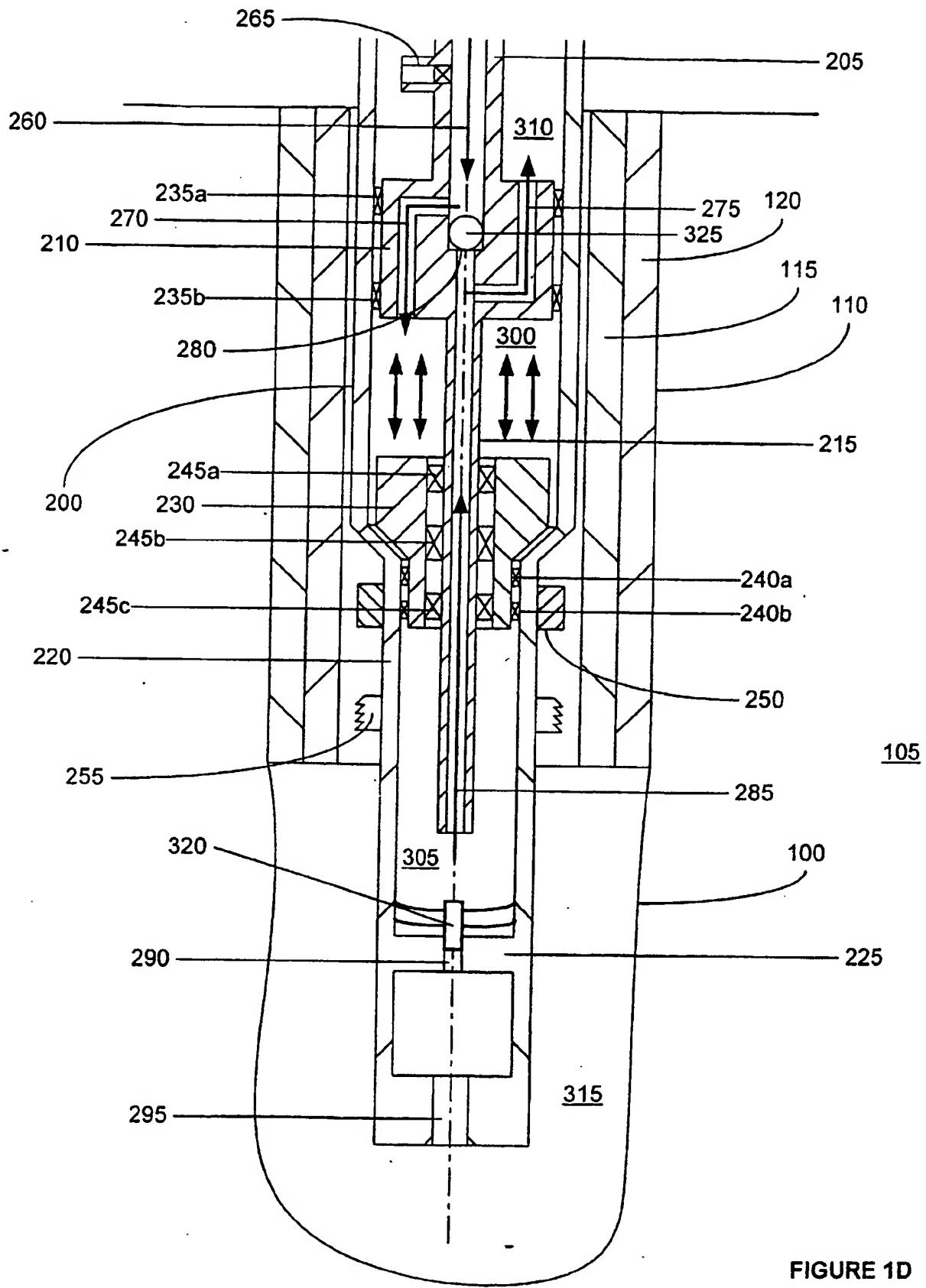


FIGURE 1D

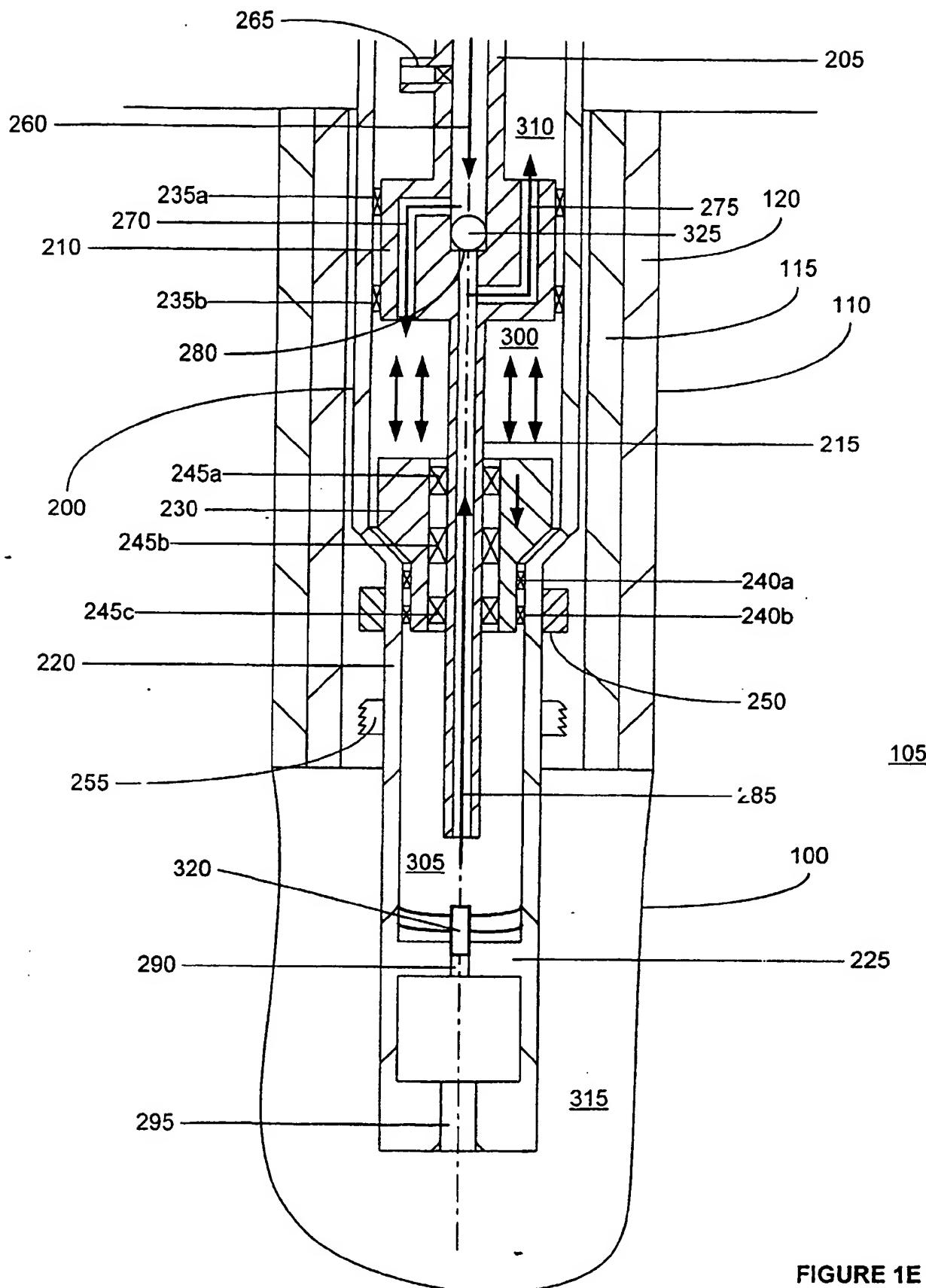


FIGURE 1E

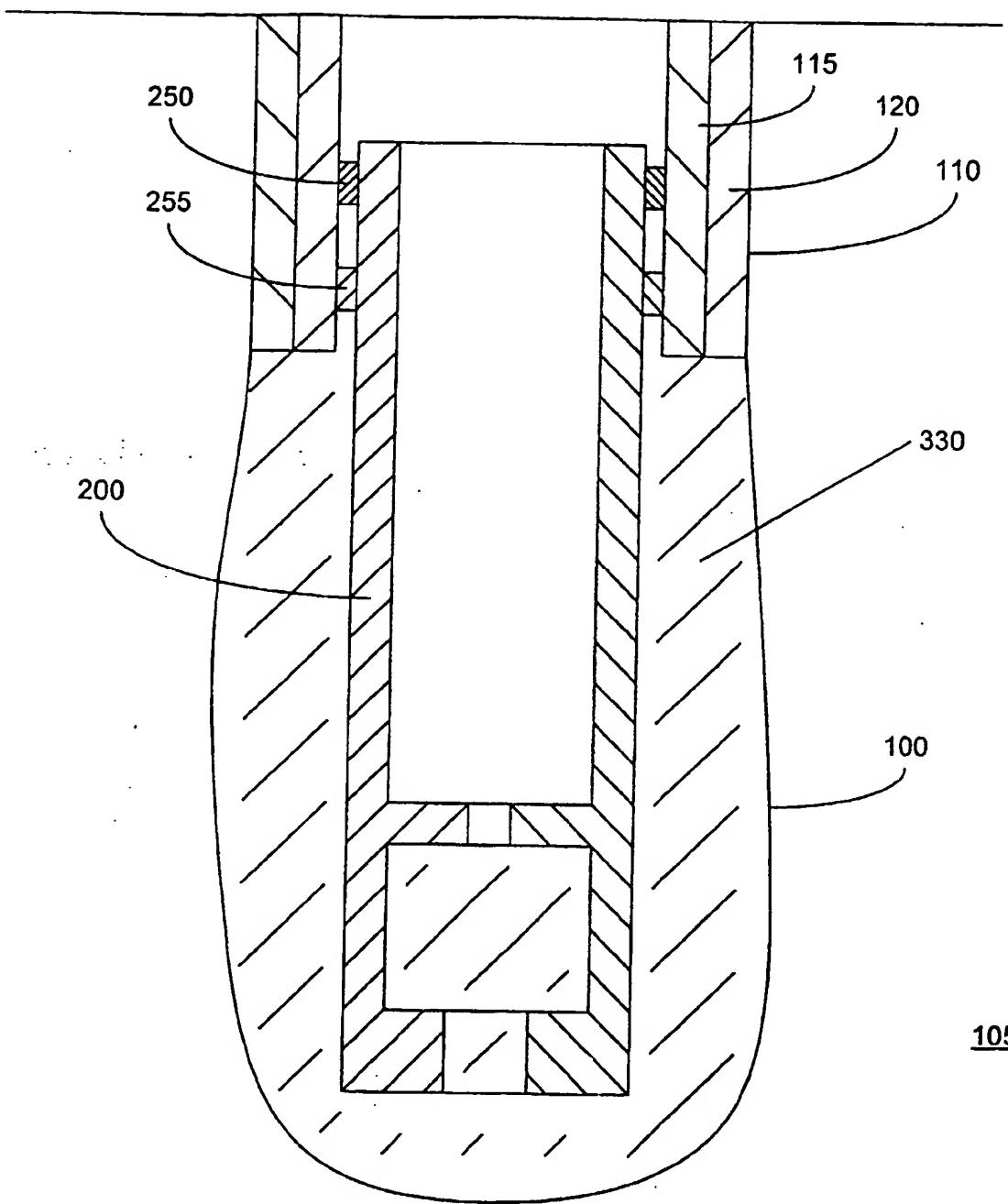


FIGURE 1F

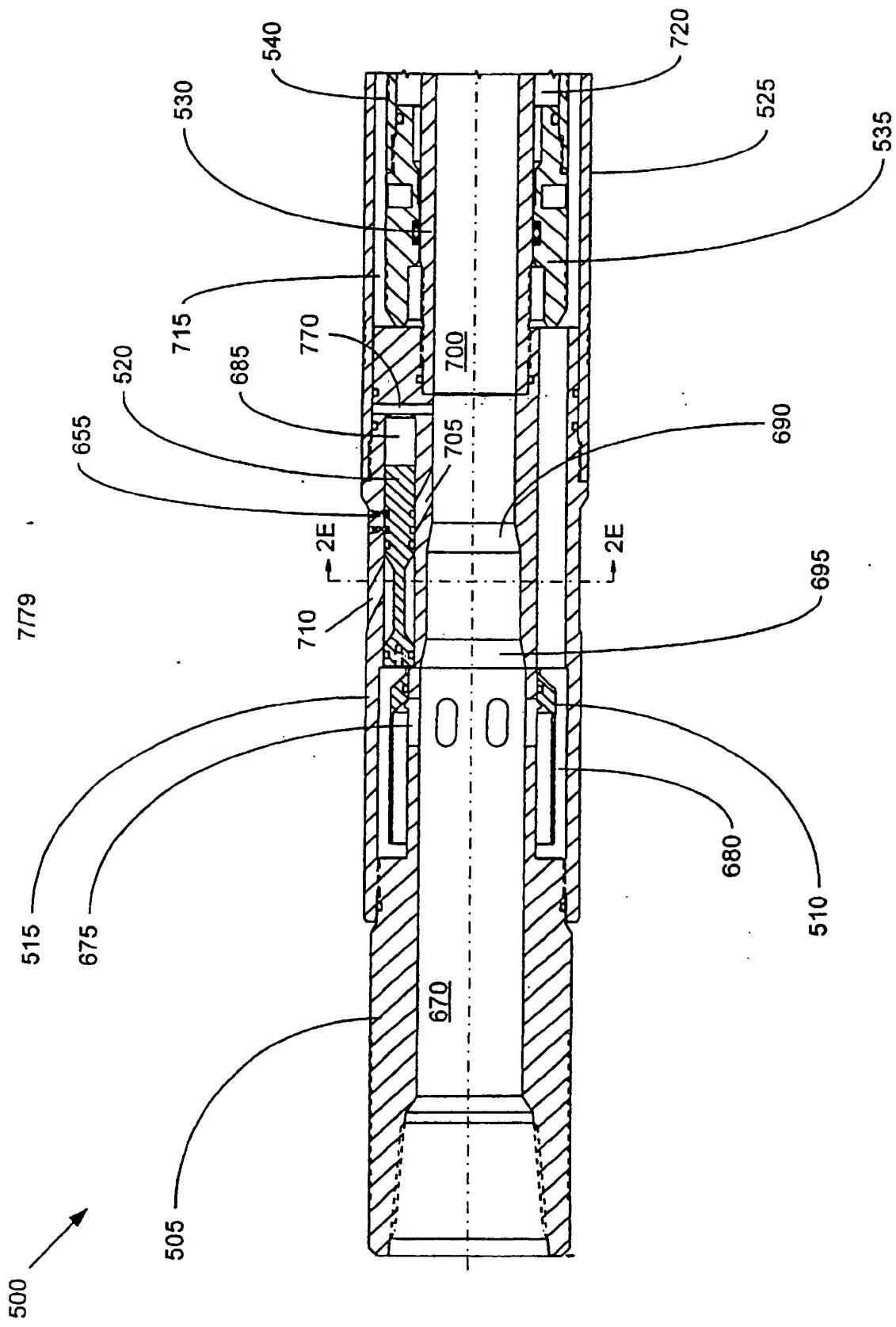


FIGURE 2A

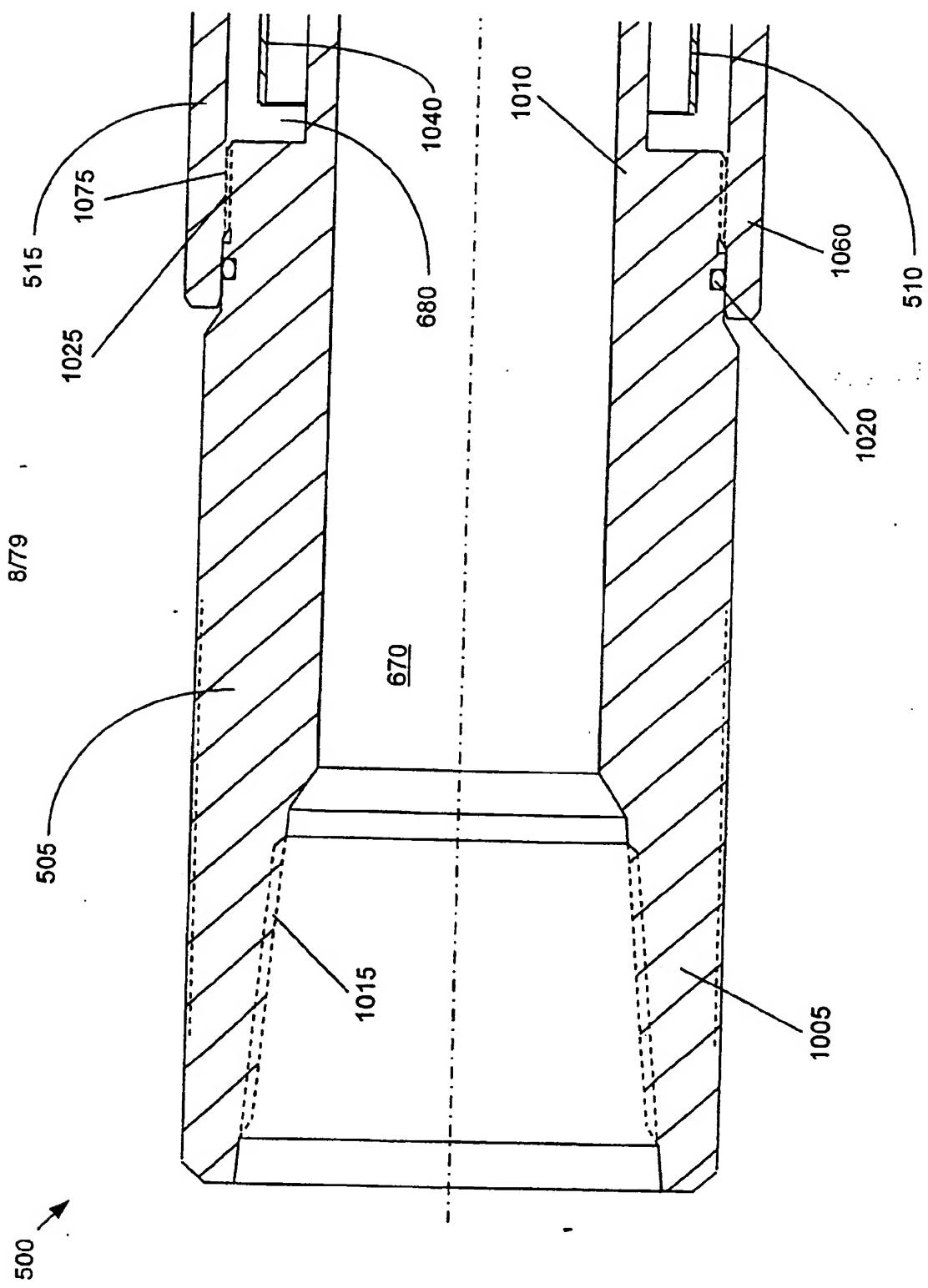


FIGURE 2B

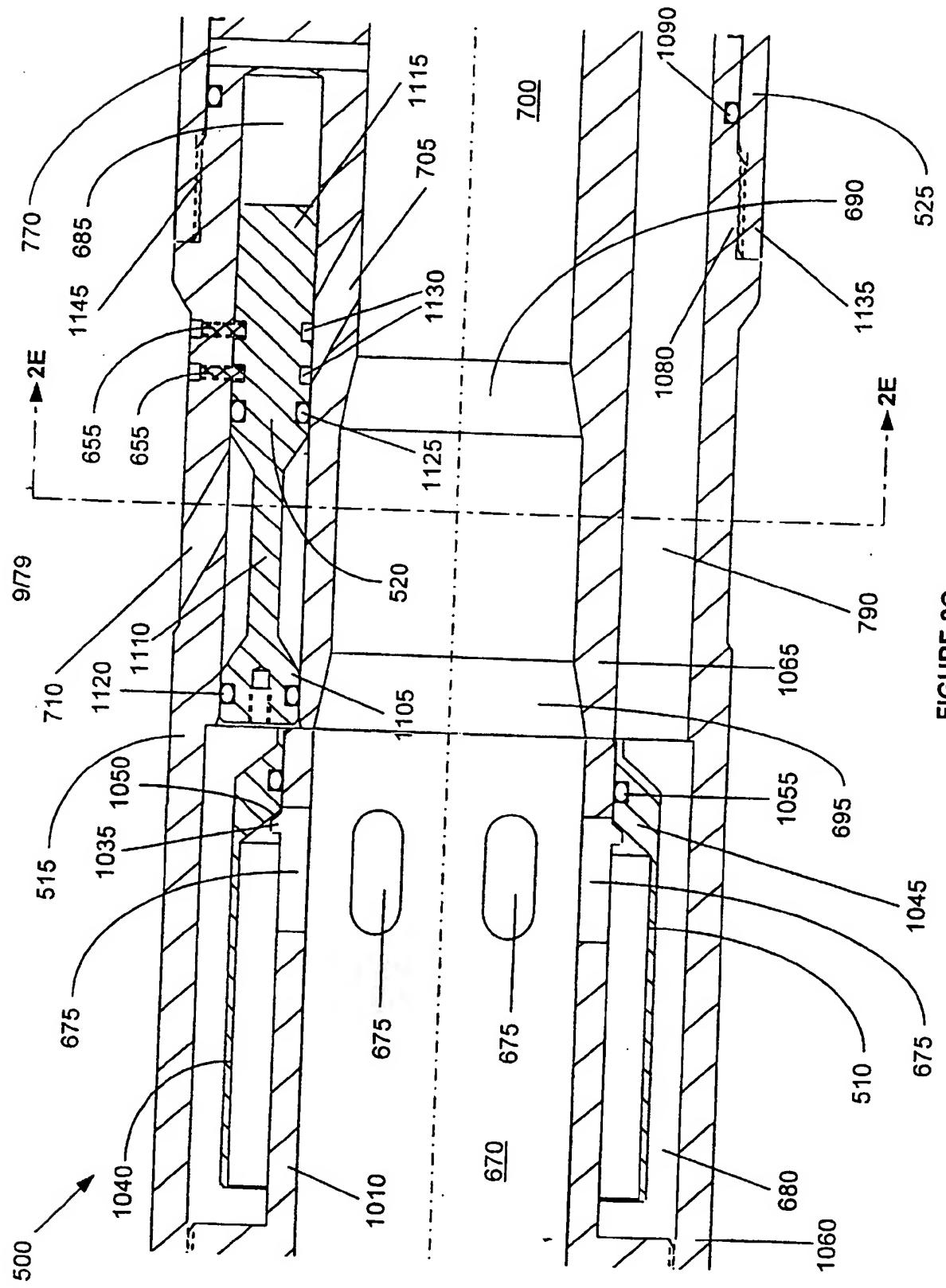
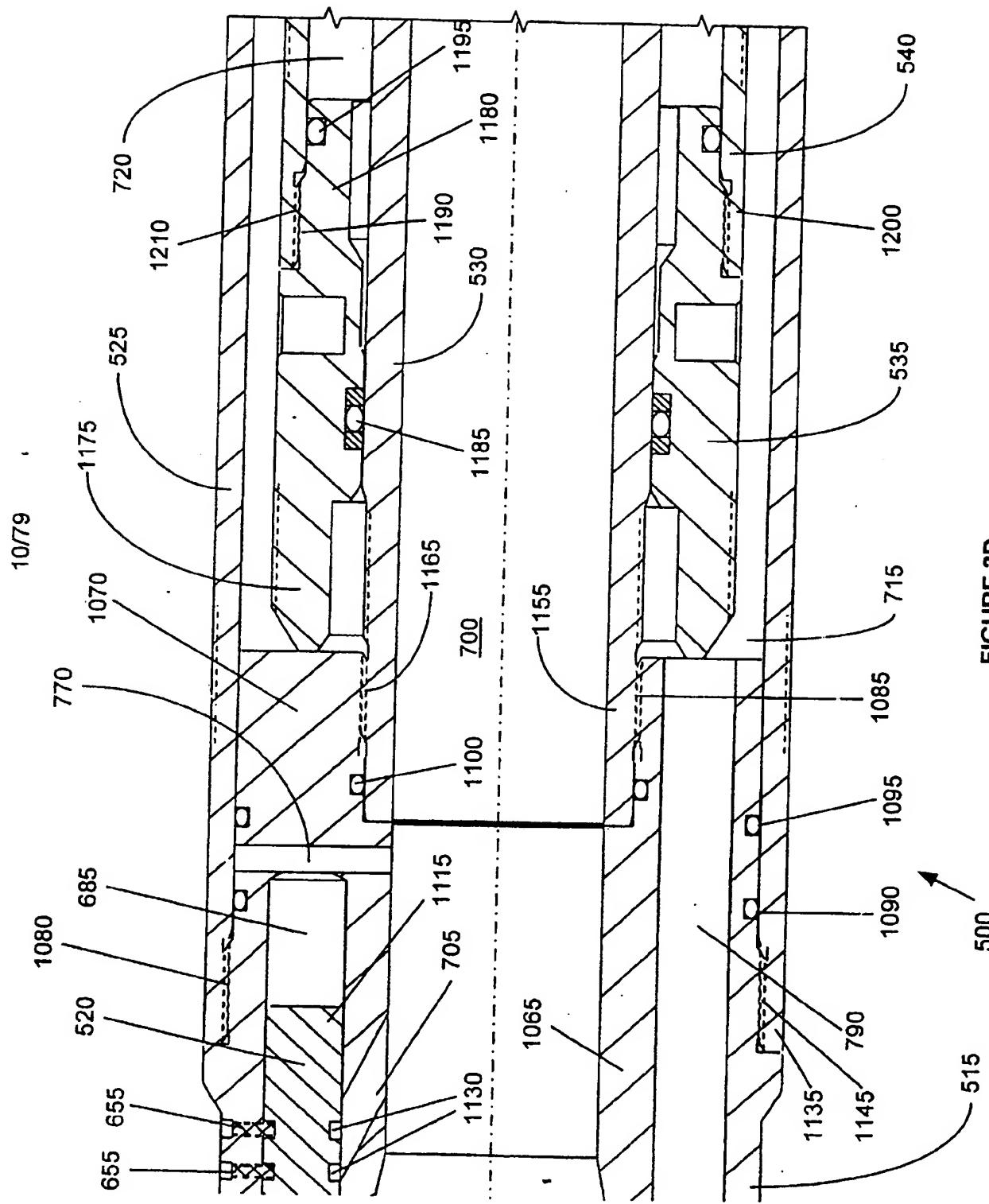


FIGURE 2C



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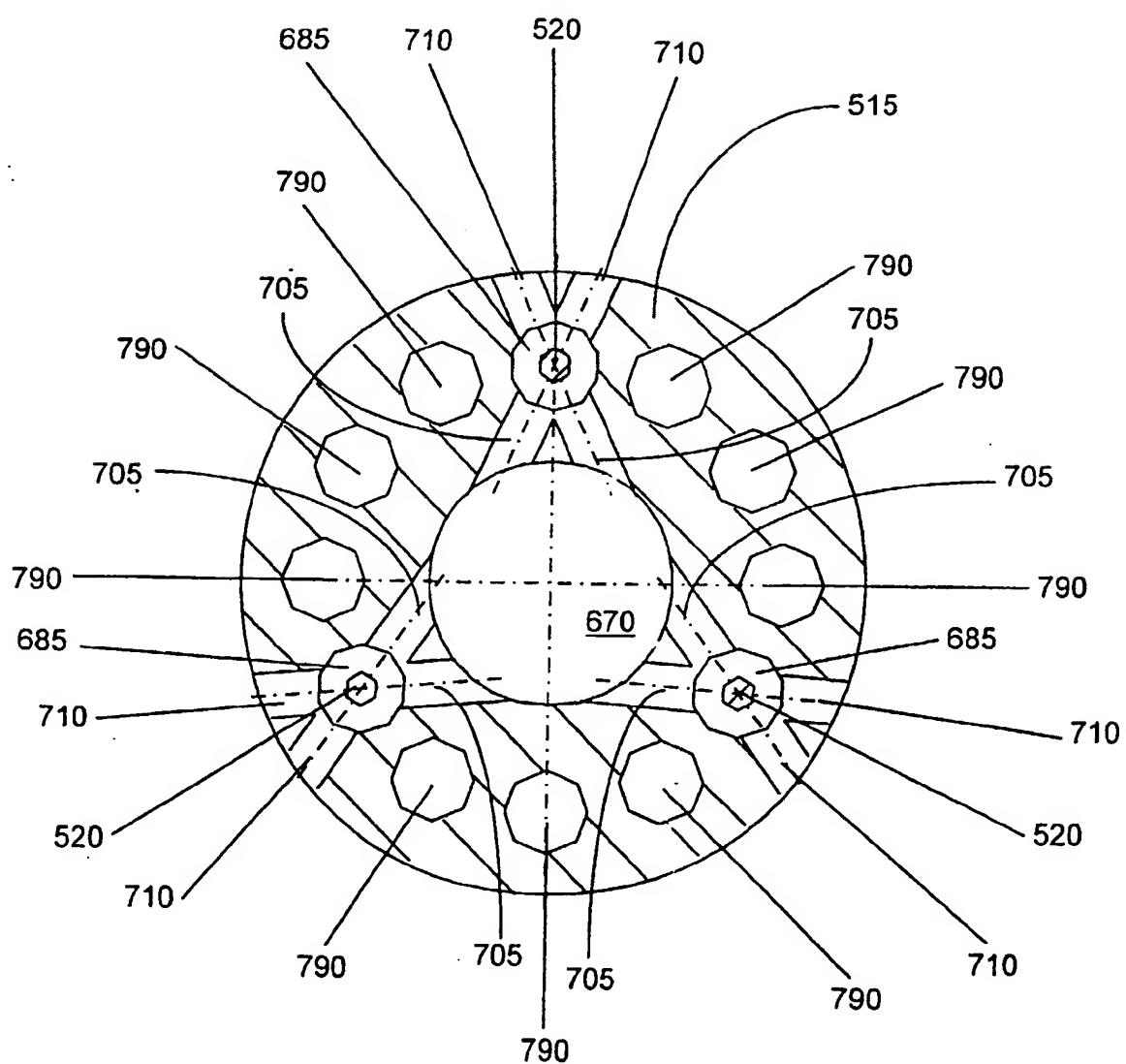


FIGURE 2E

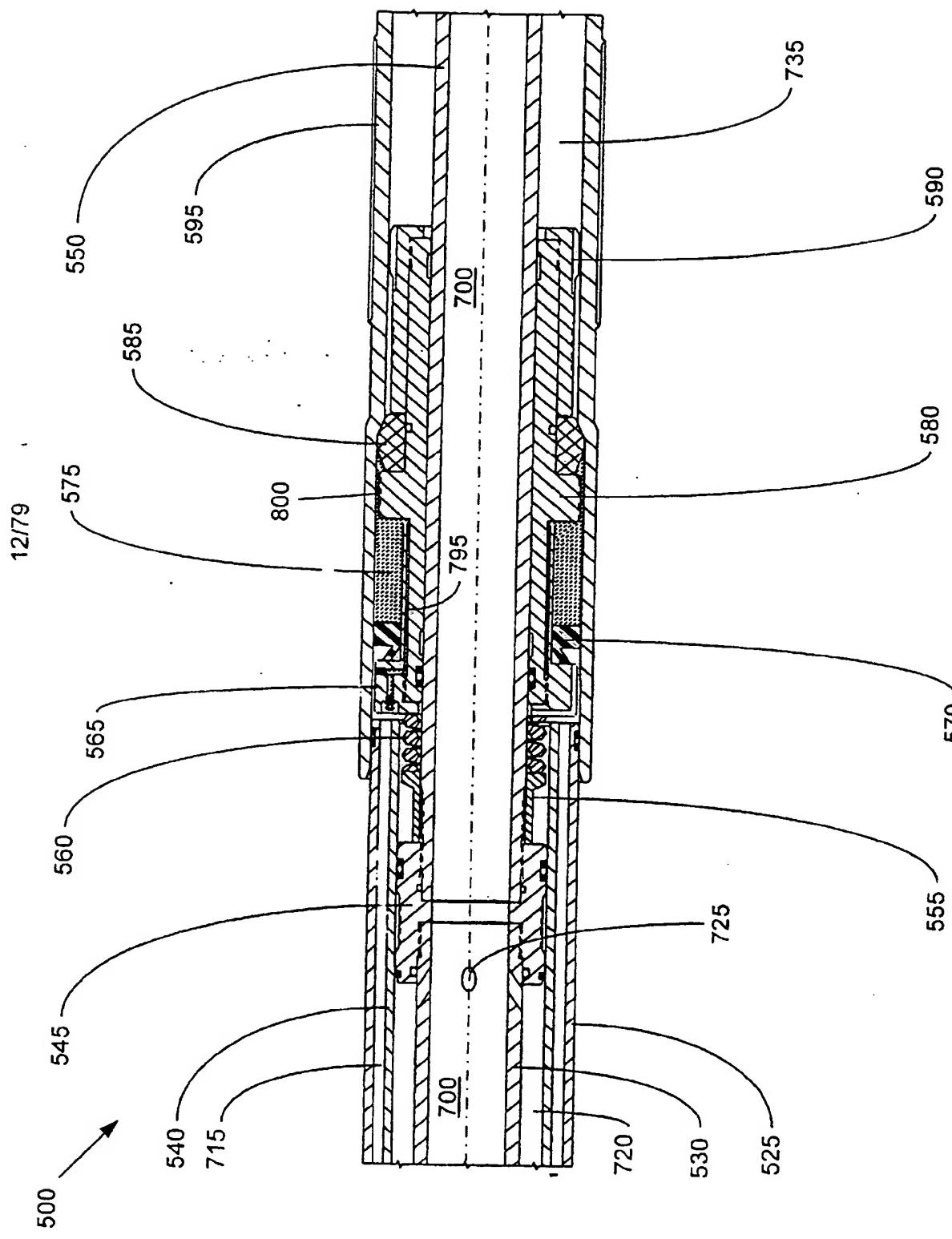


FIGURE 2F

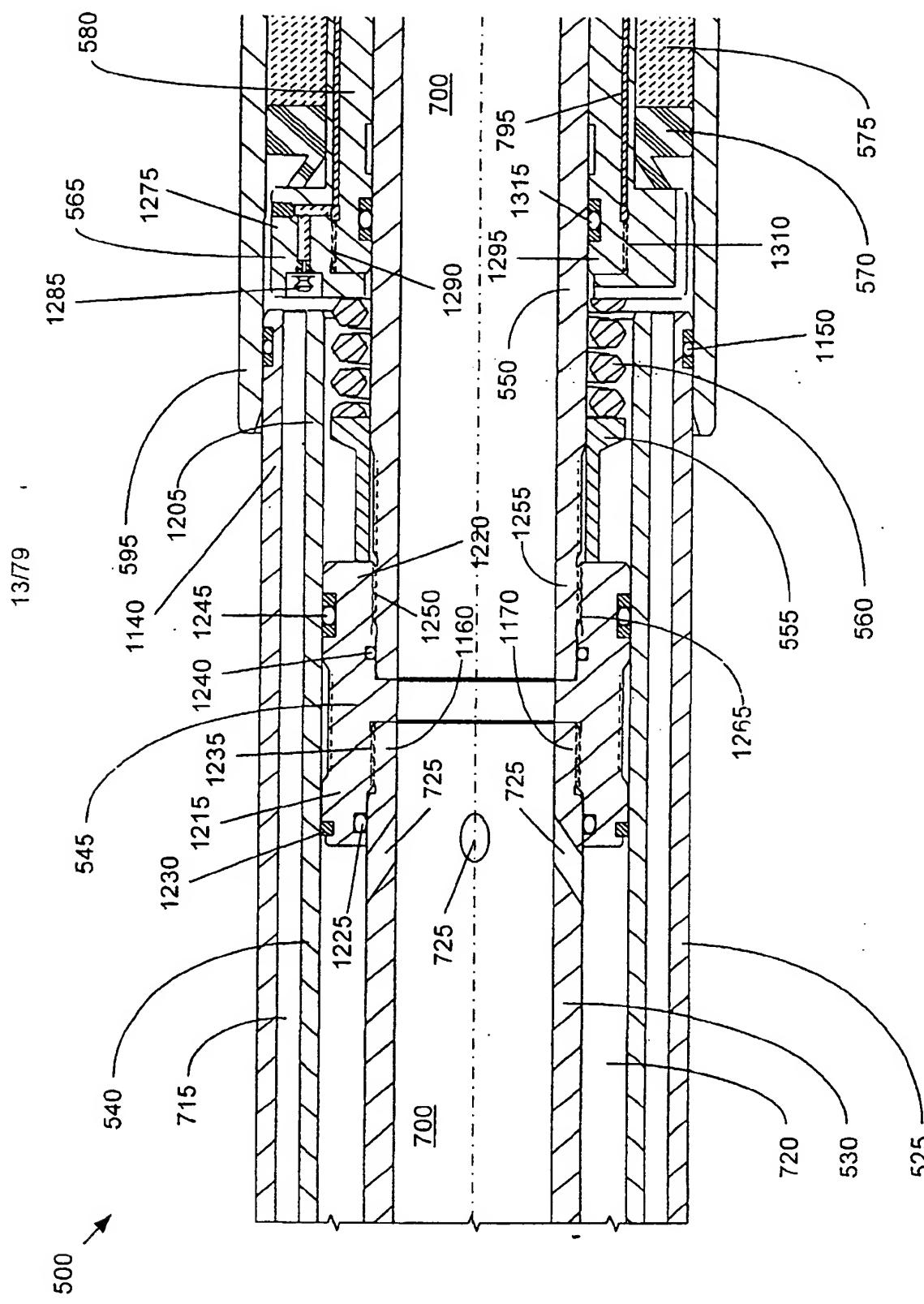


FIGURE 2G

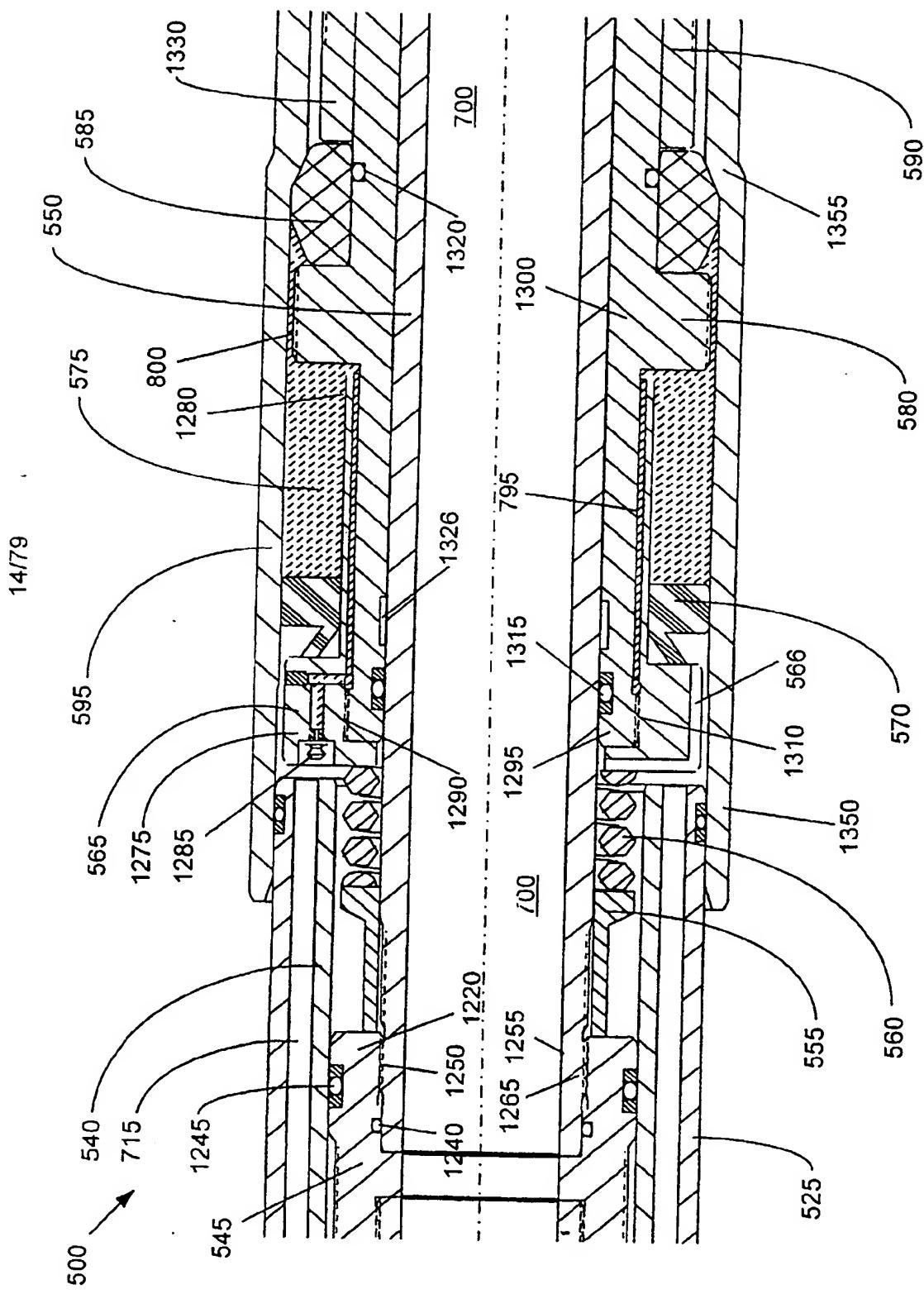


FIGURE 2H

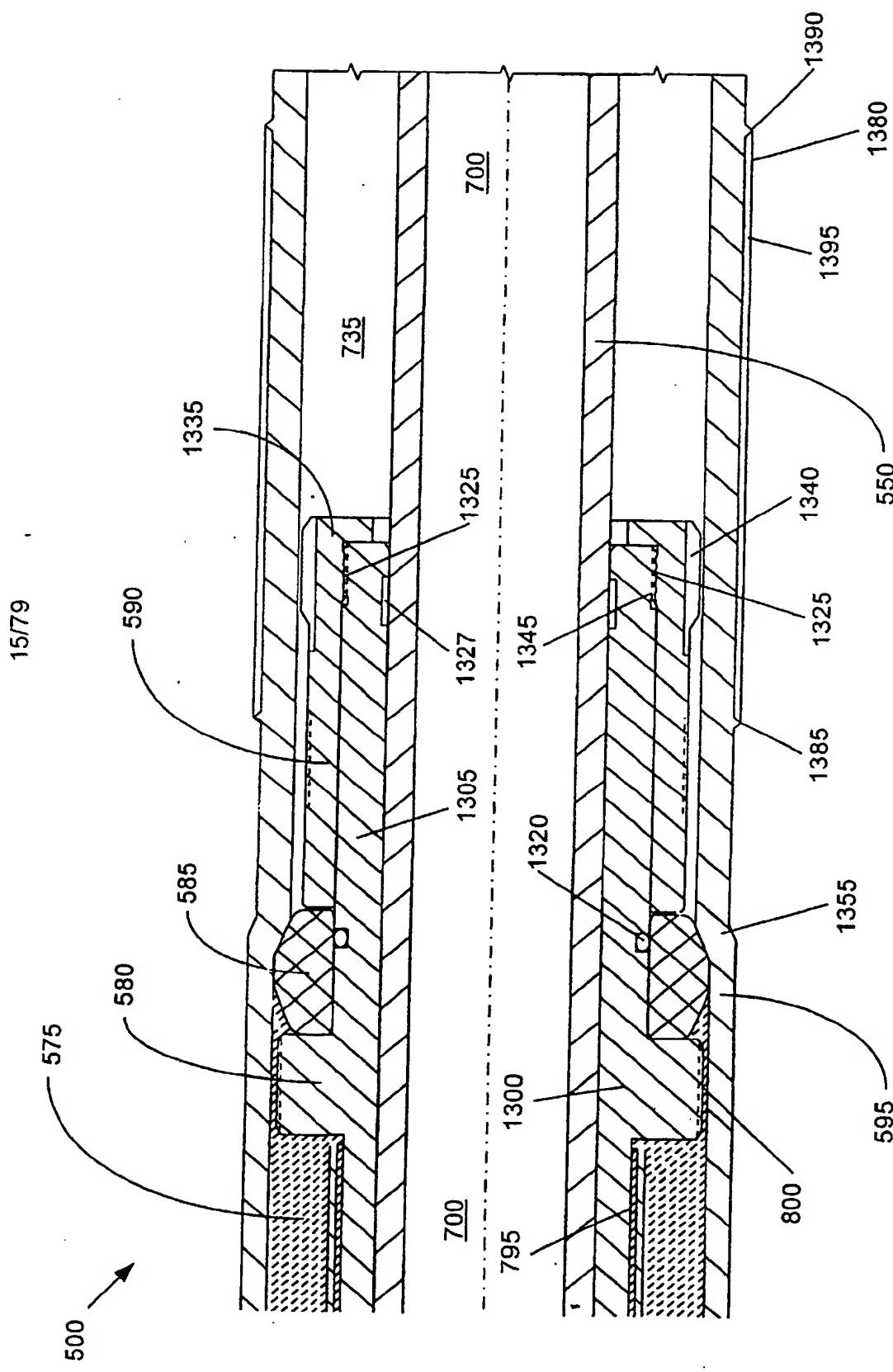


FIGURE 21

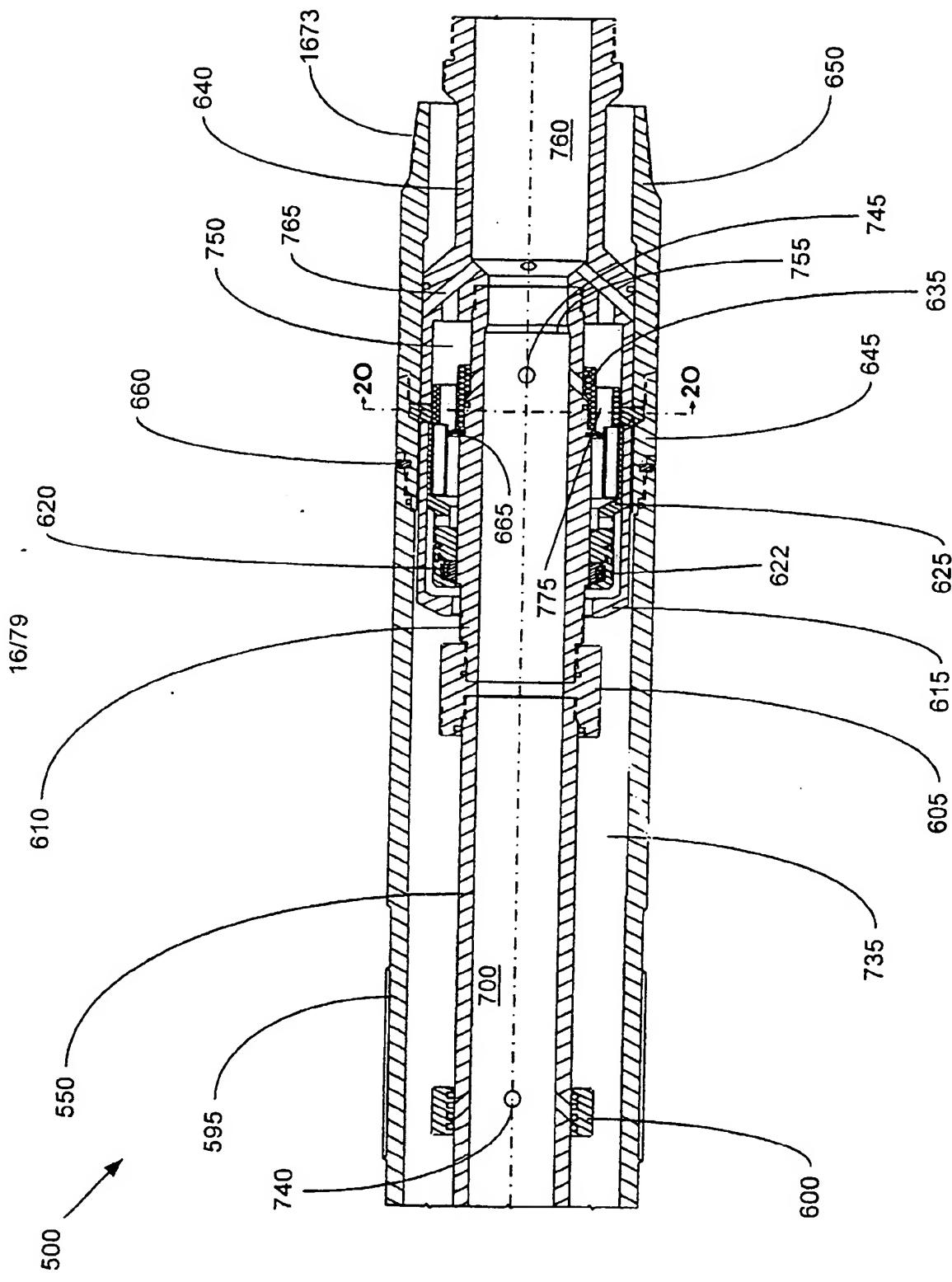


FIGURE 2J

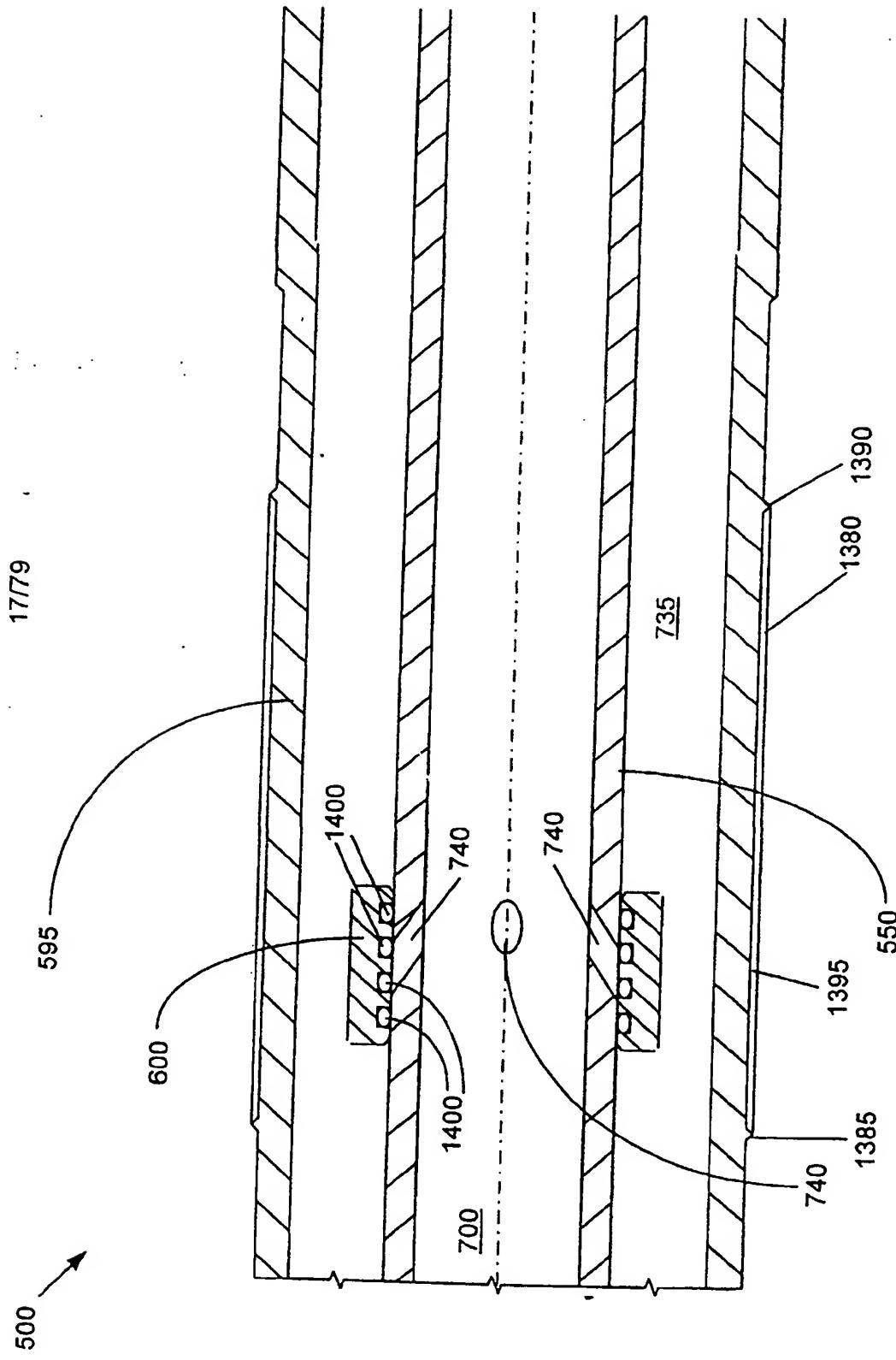


FIGURE 2K

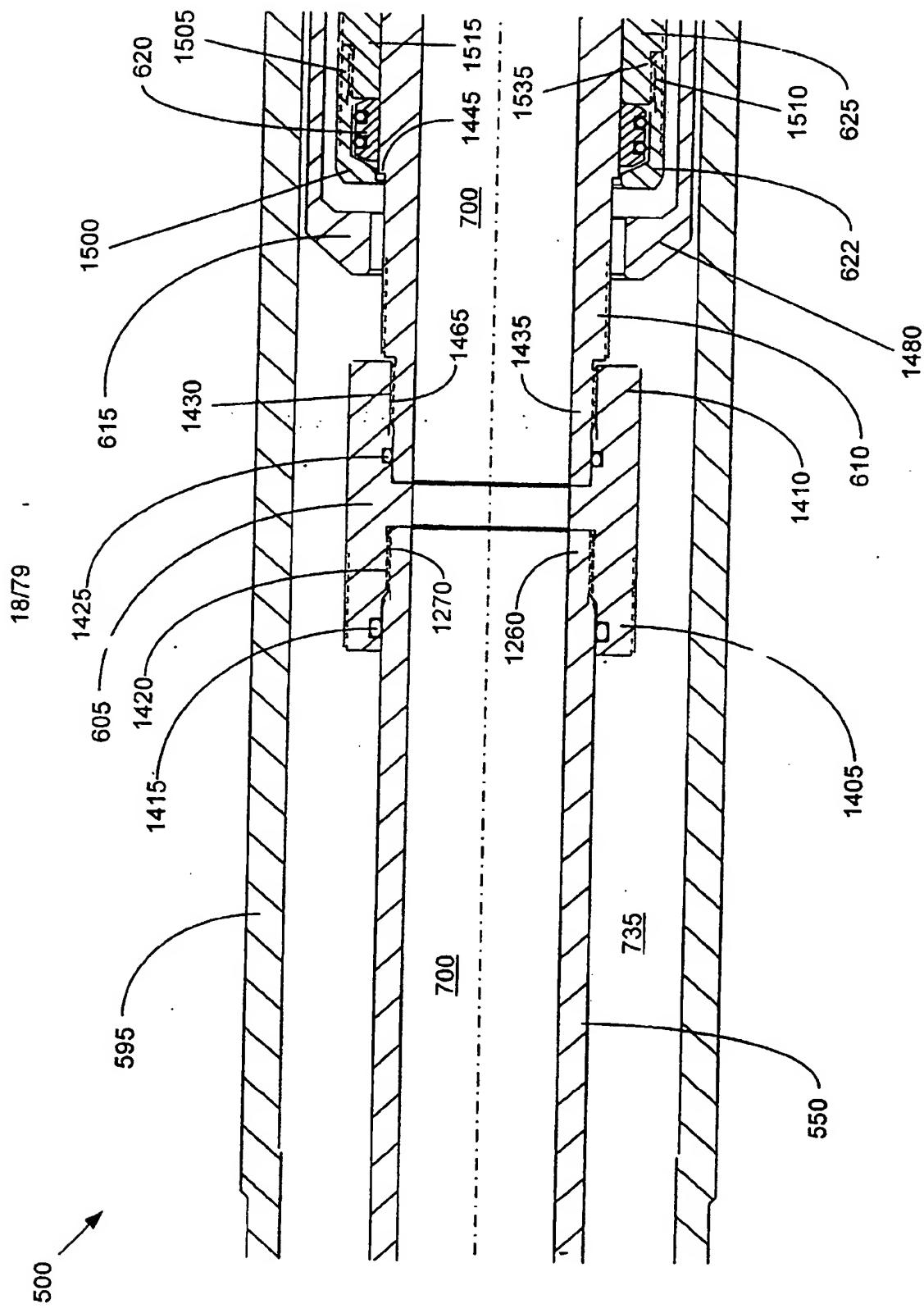


FIGURE 2L

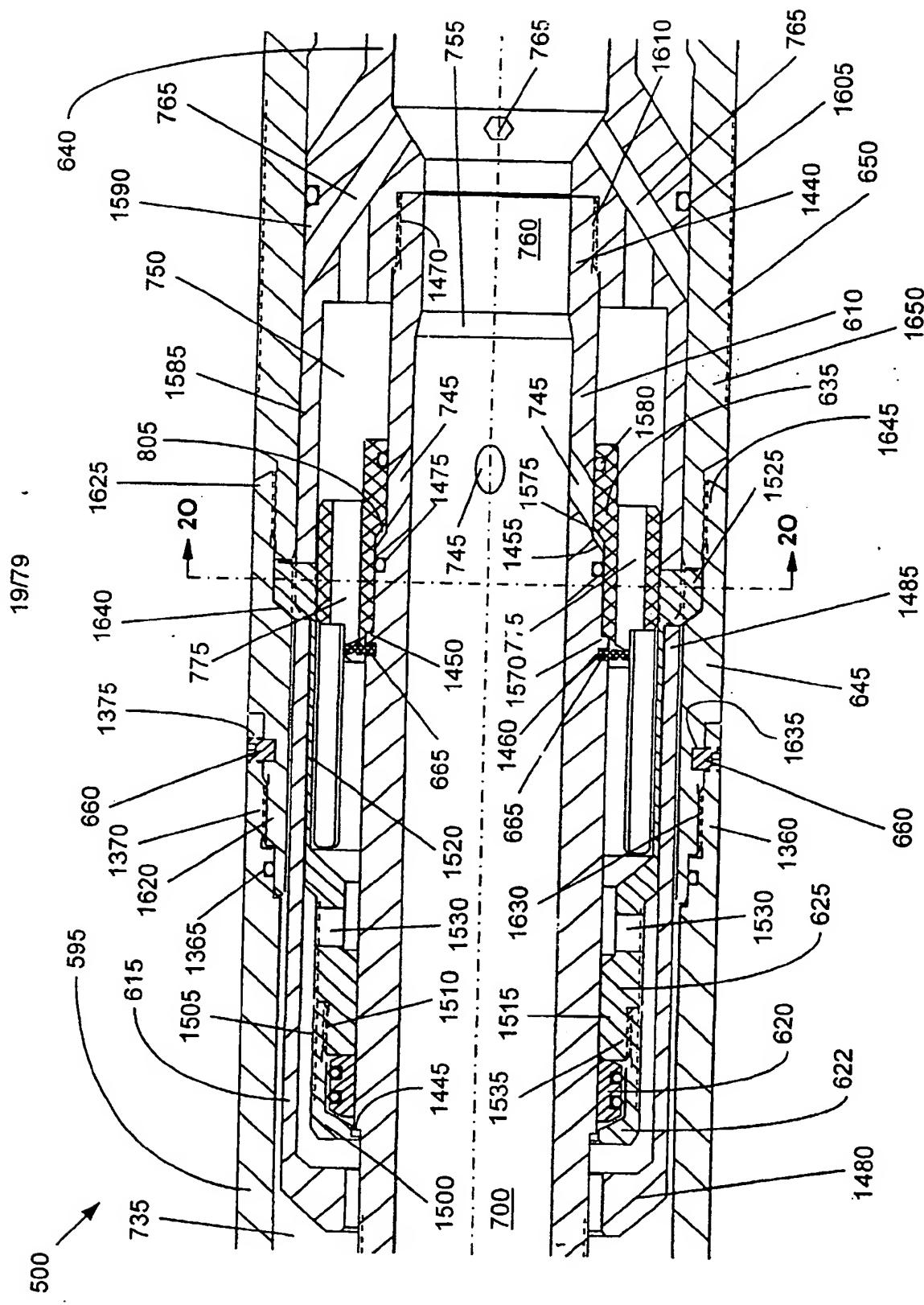


FIGURE 2M

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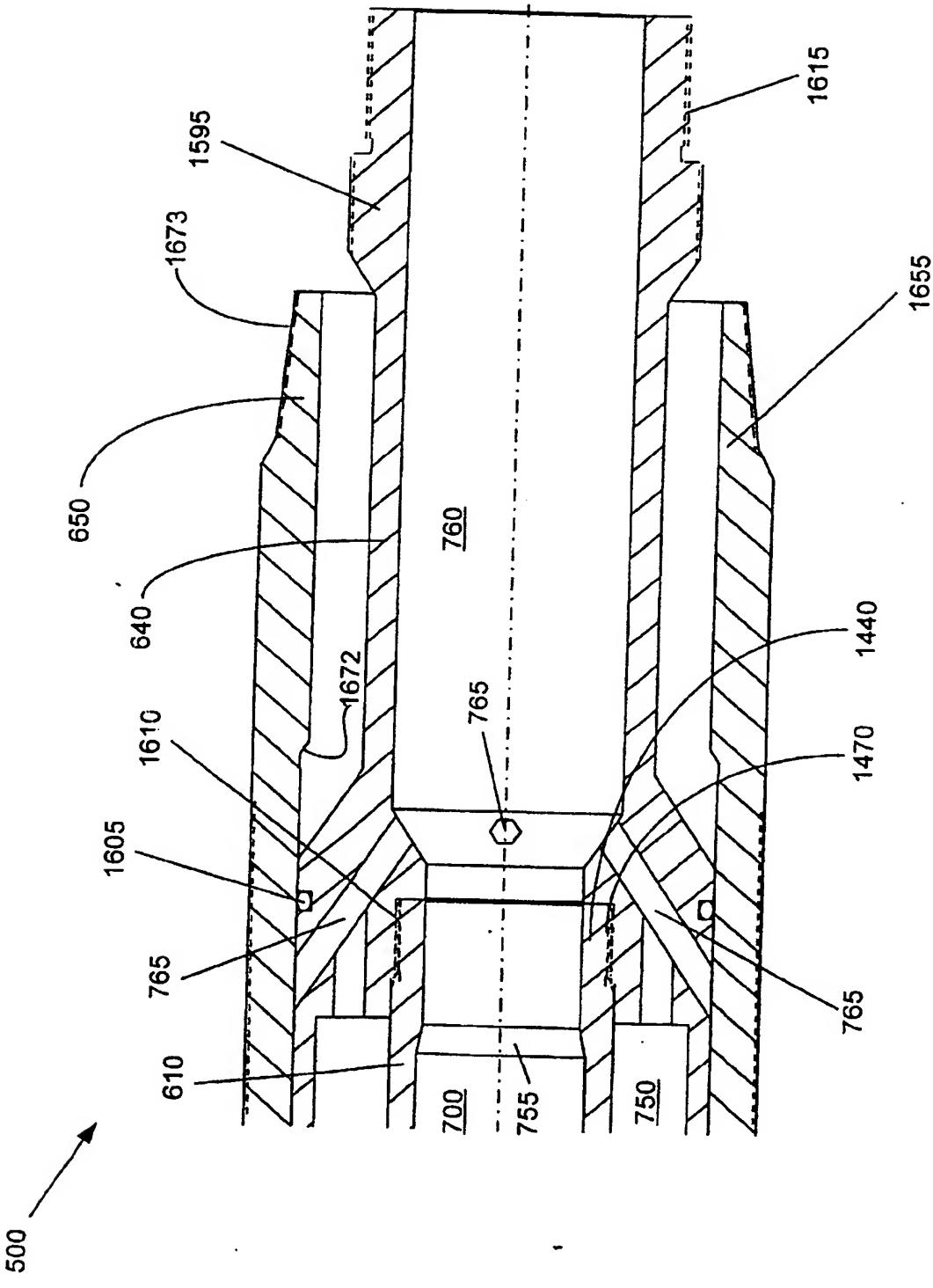


FIGURE 2N

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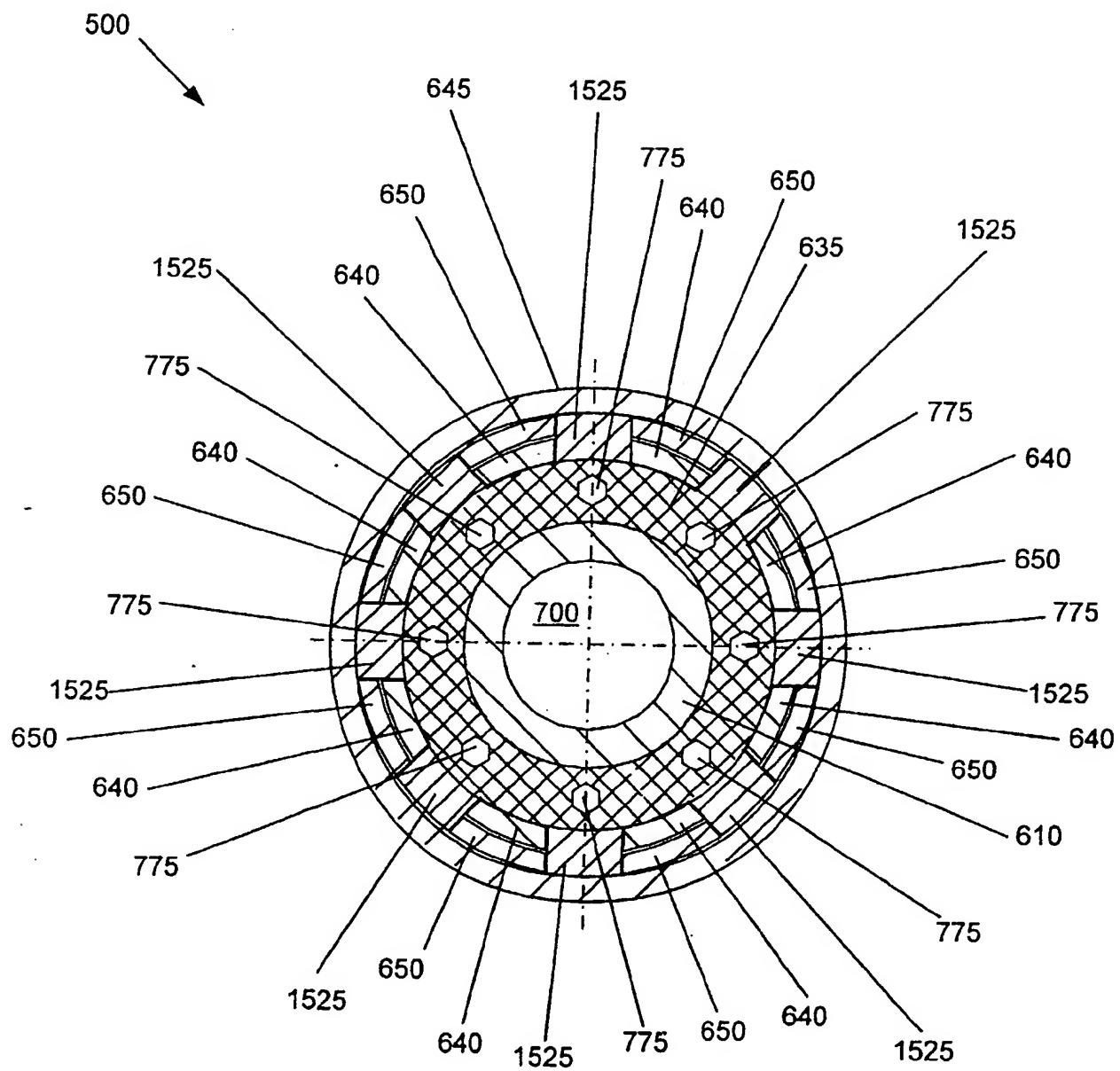
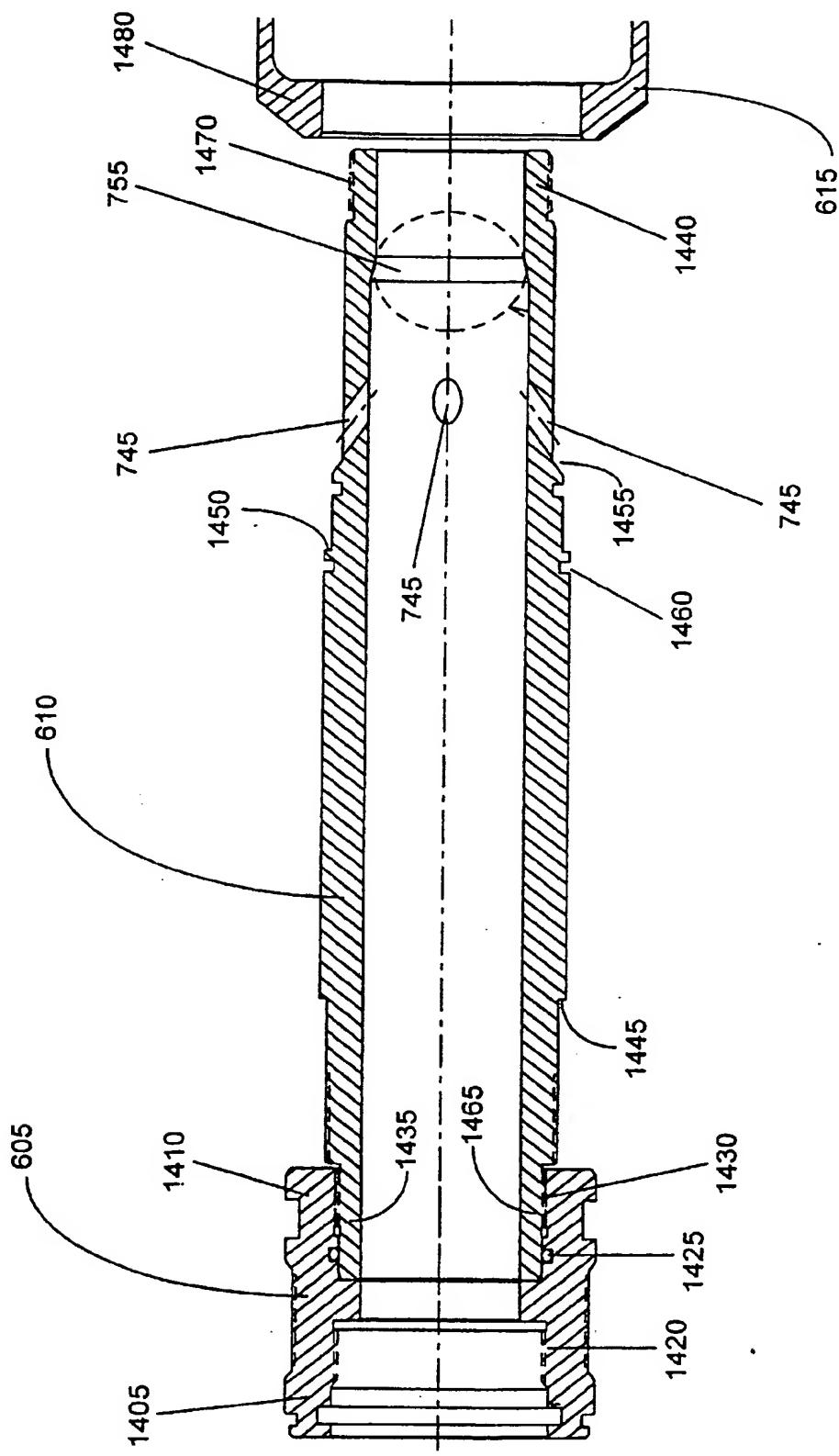


FIGURE 20

FIGURE 3A

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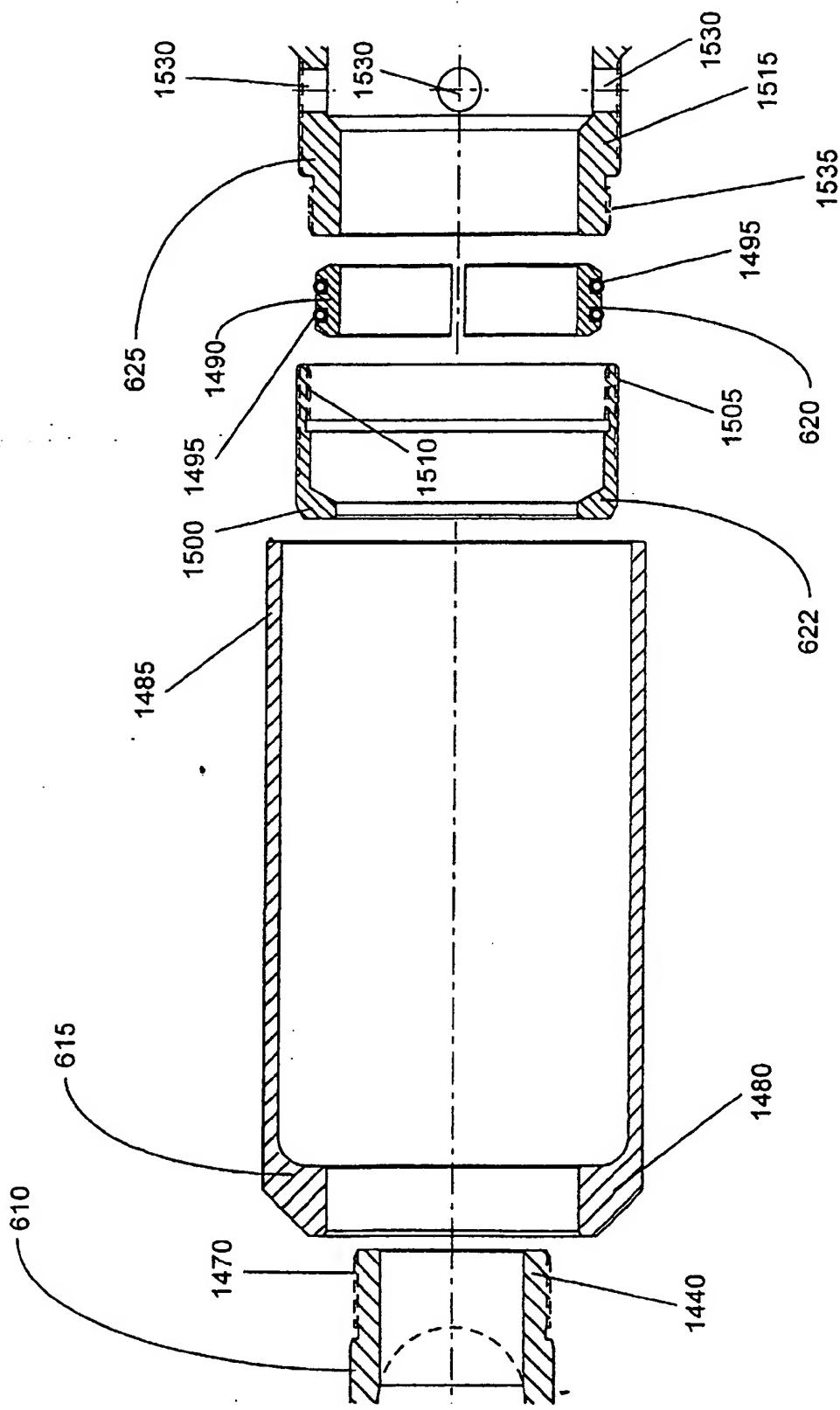


FIGURE 3B

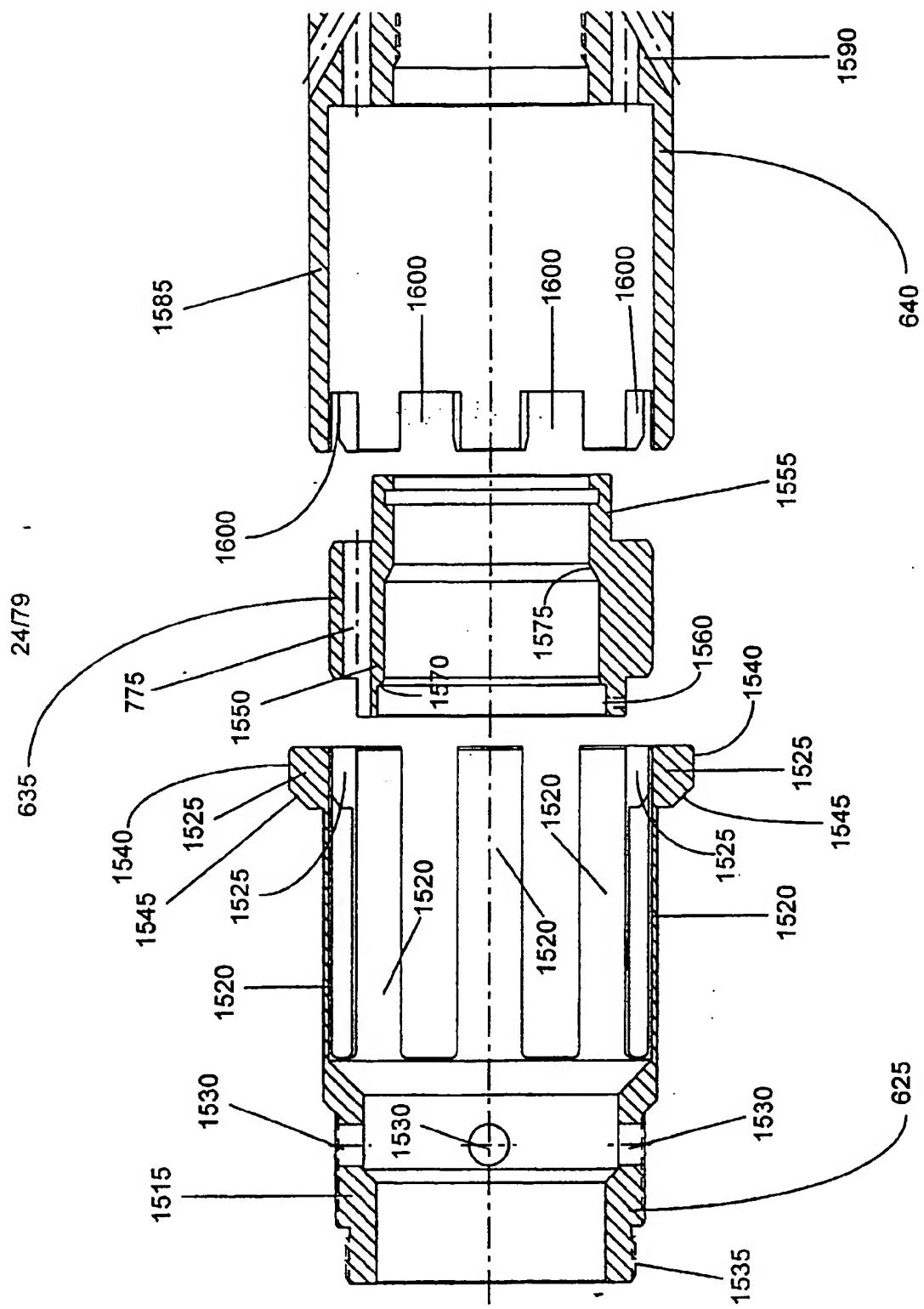


FIGURE 3C

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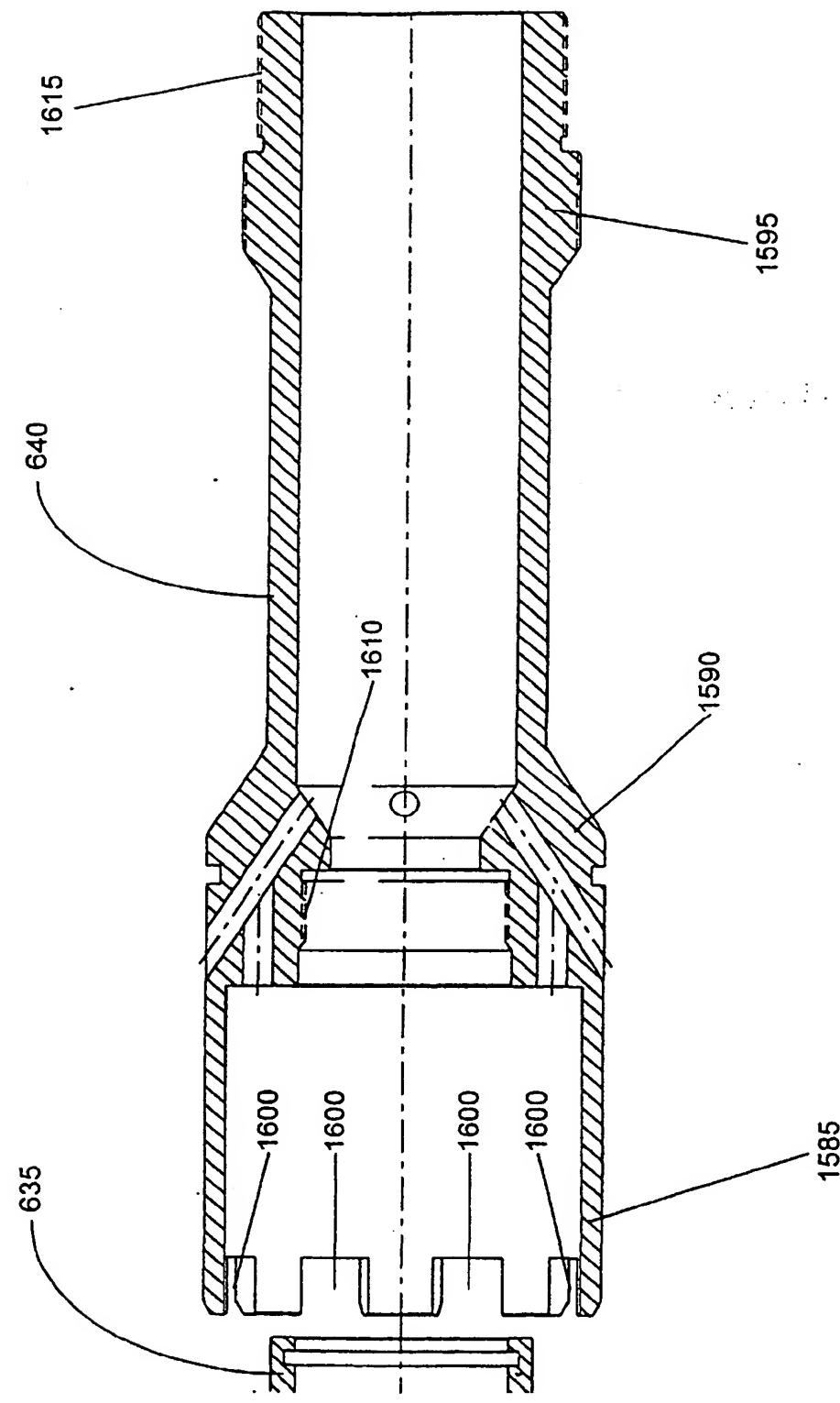


FIGURE 3D

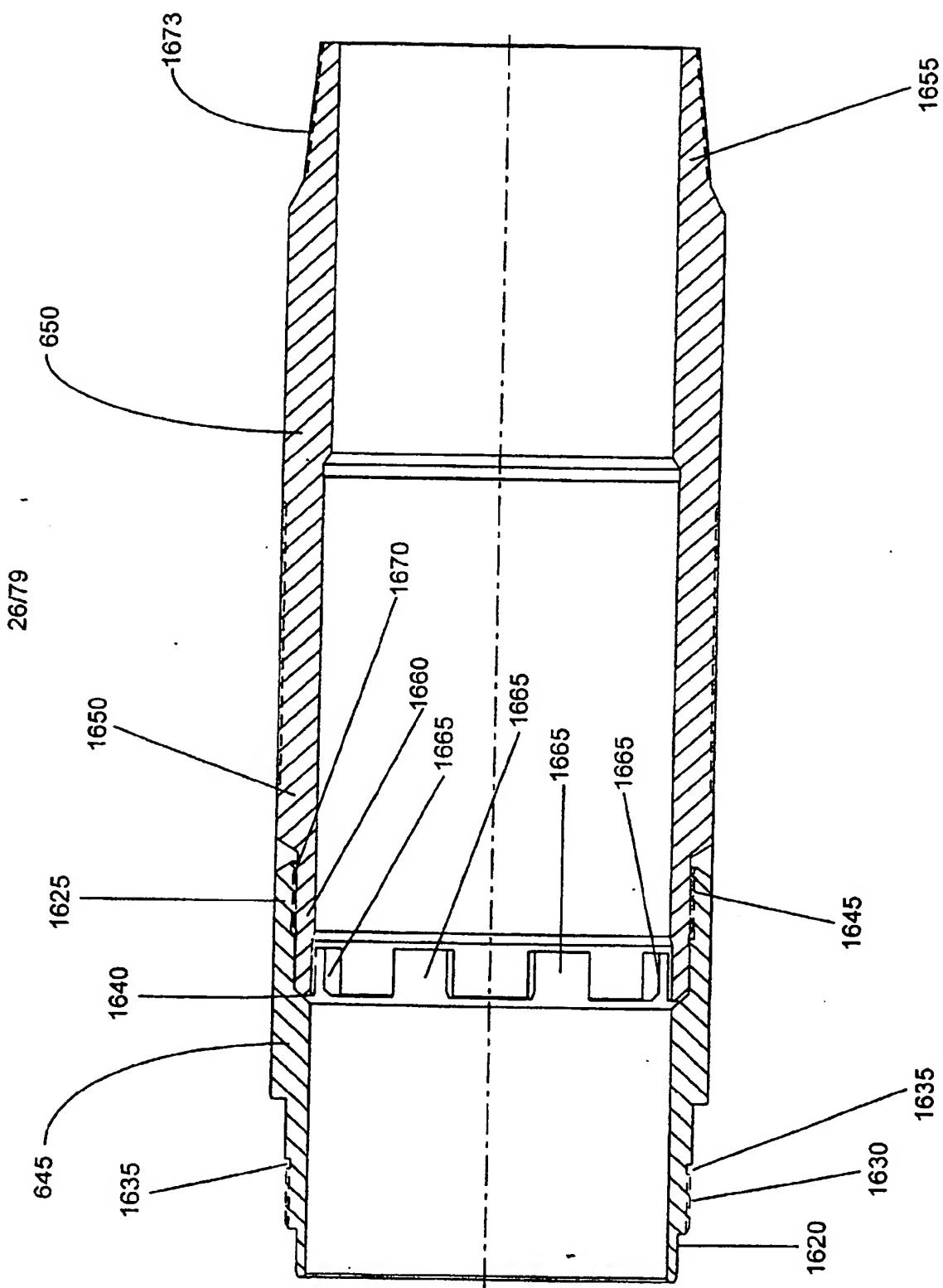


FIGURE 3E

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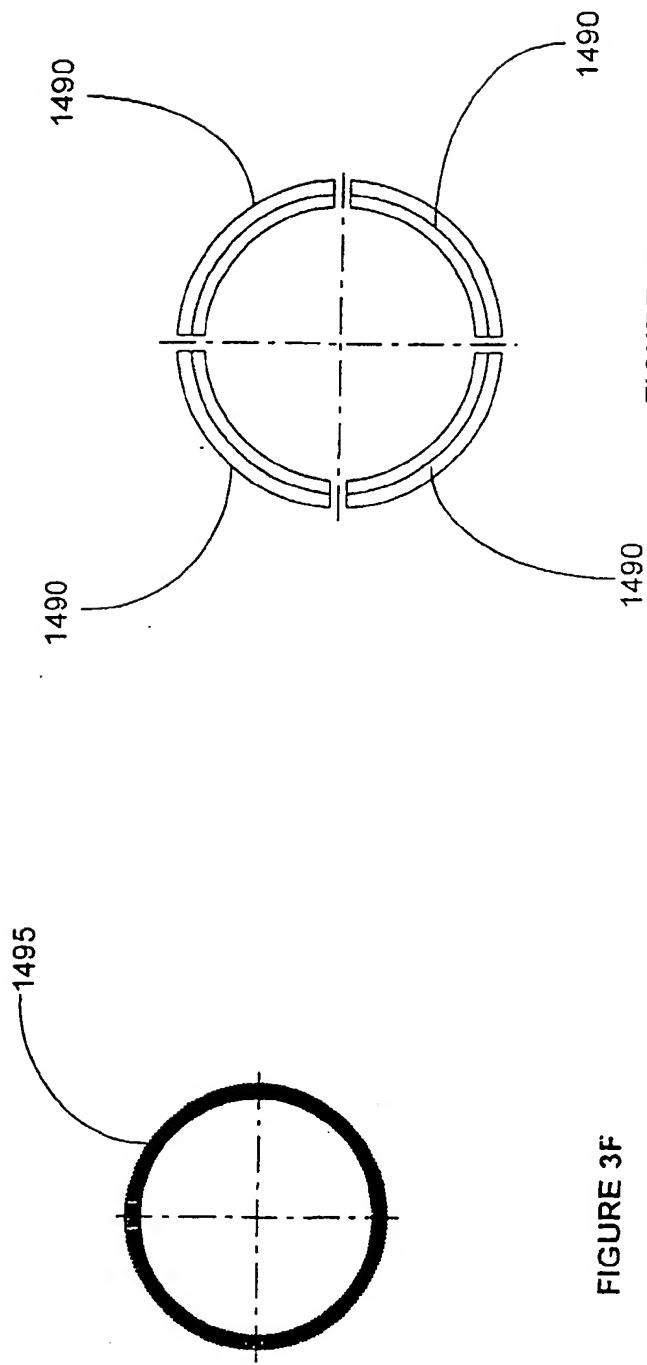


FIGURE 3F

FIGURE 3G

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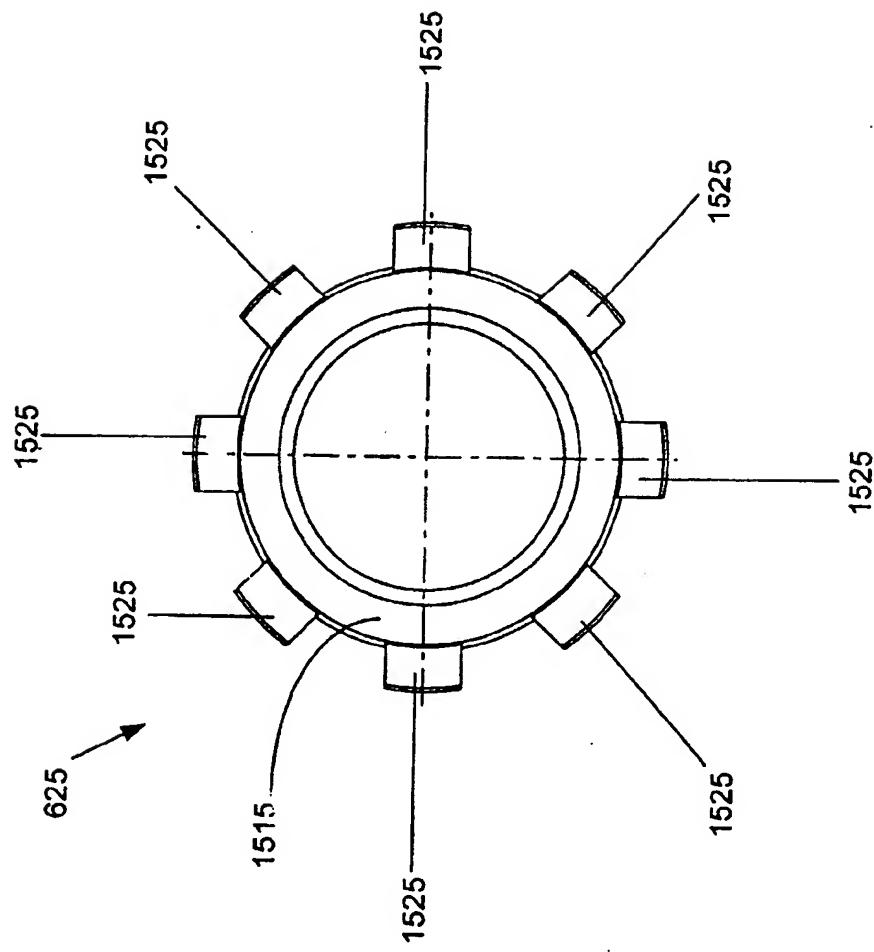


FIGURE 3H

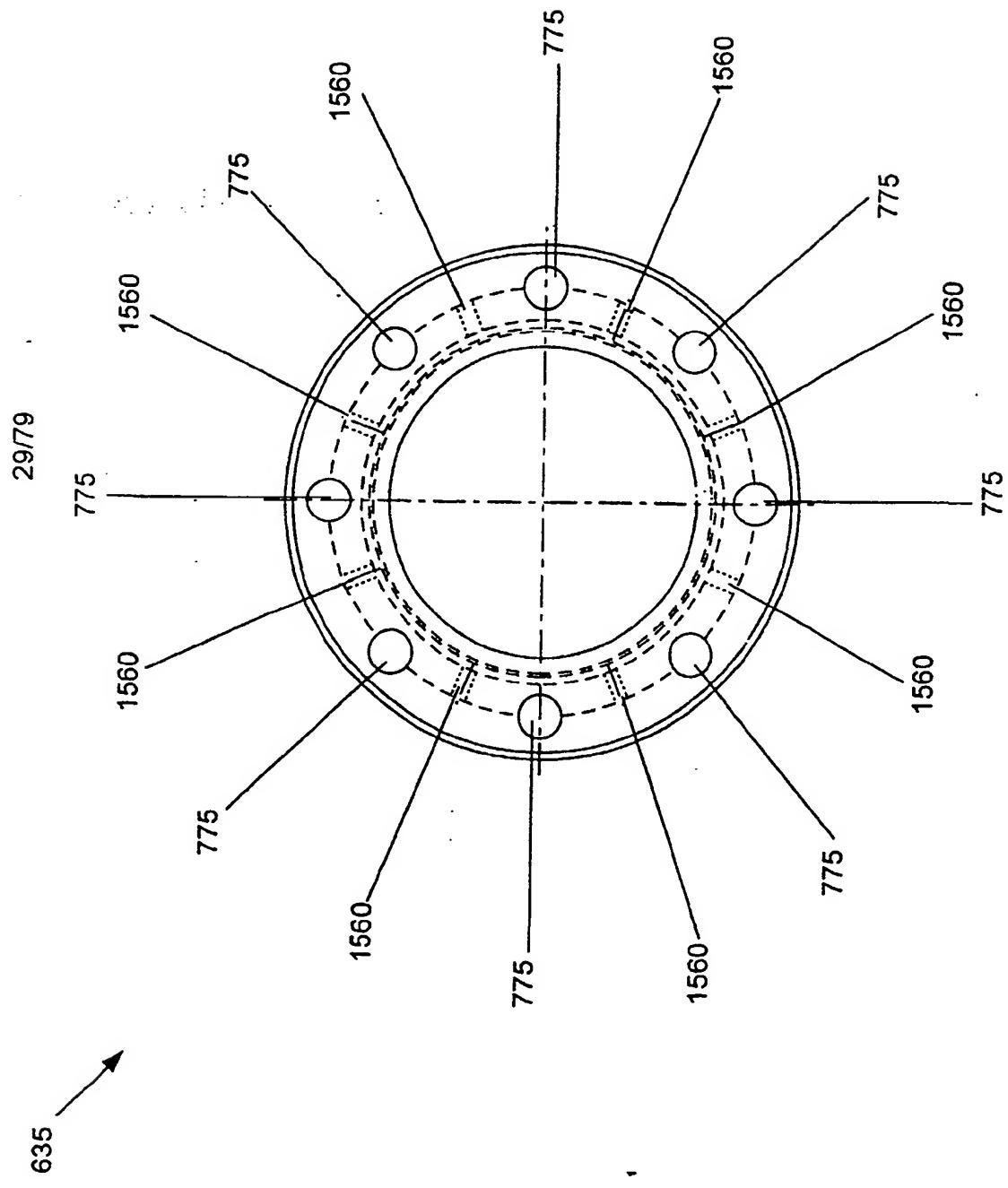


FIGURE 31

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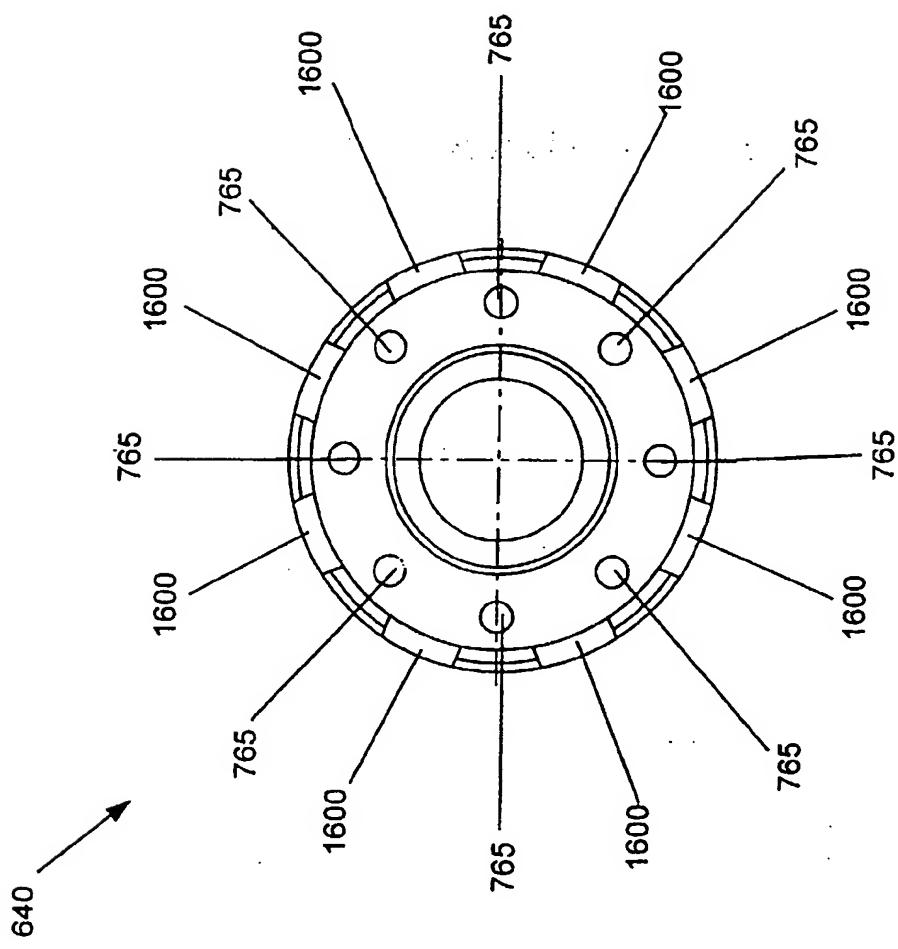


FIGURE 3J

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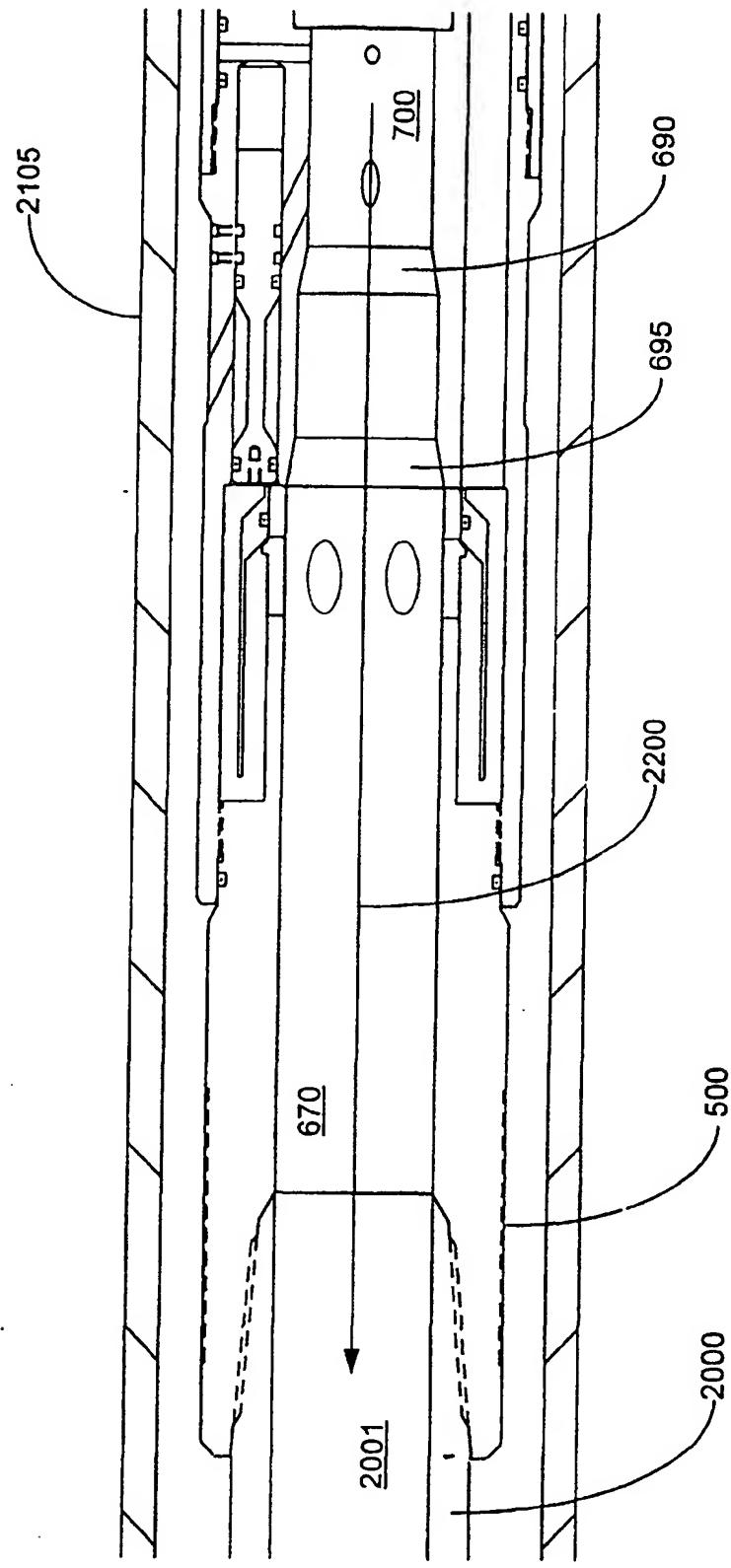


FIGURE 4A

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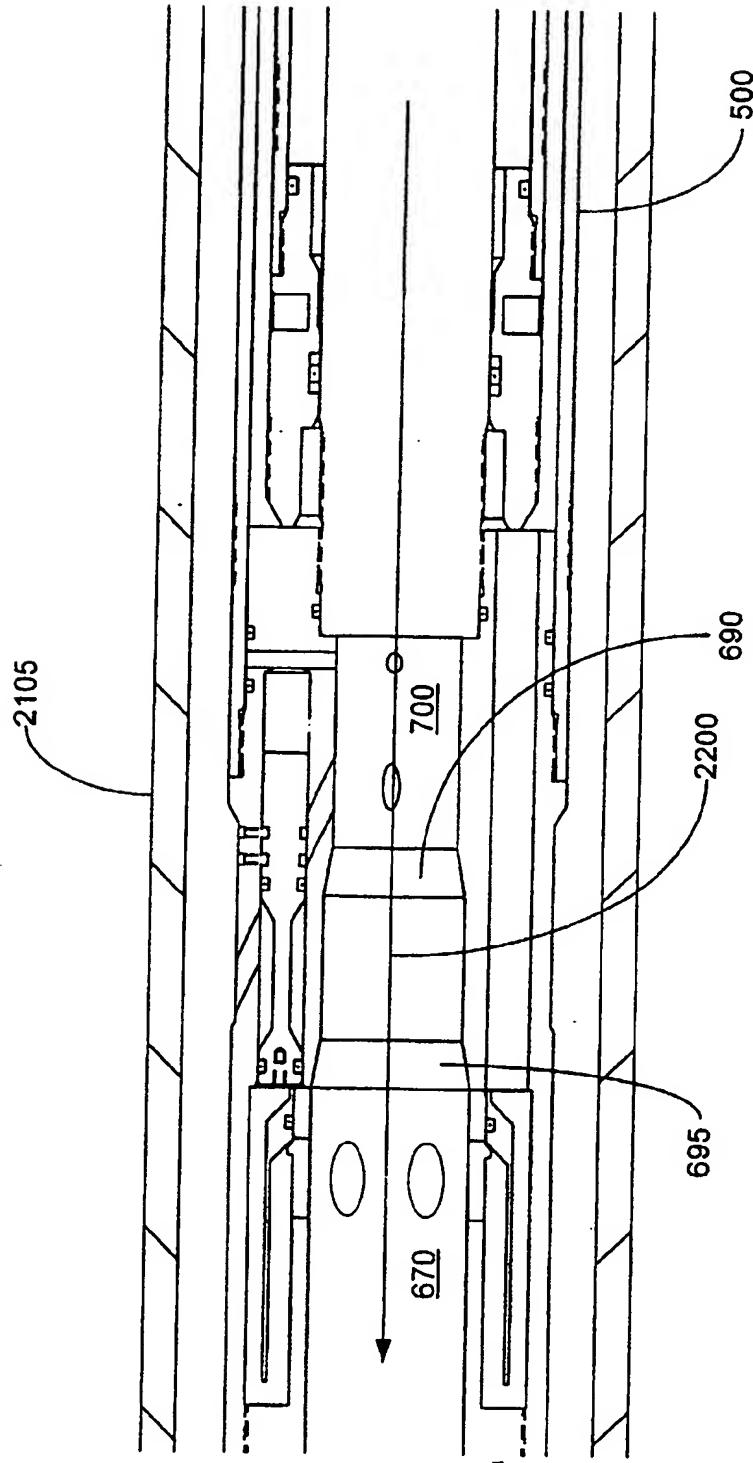
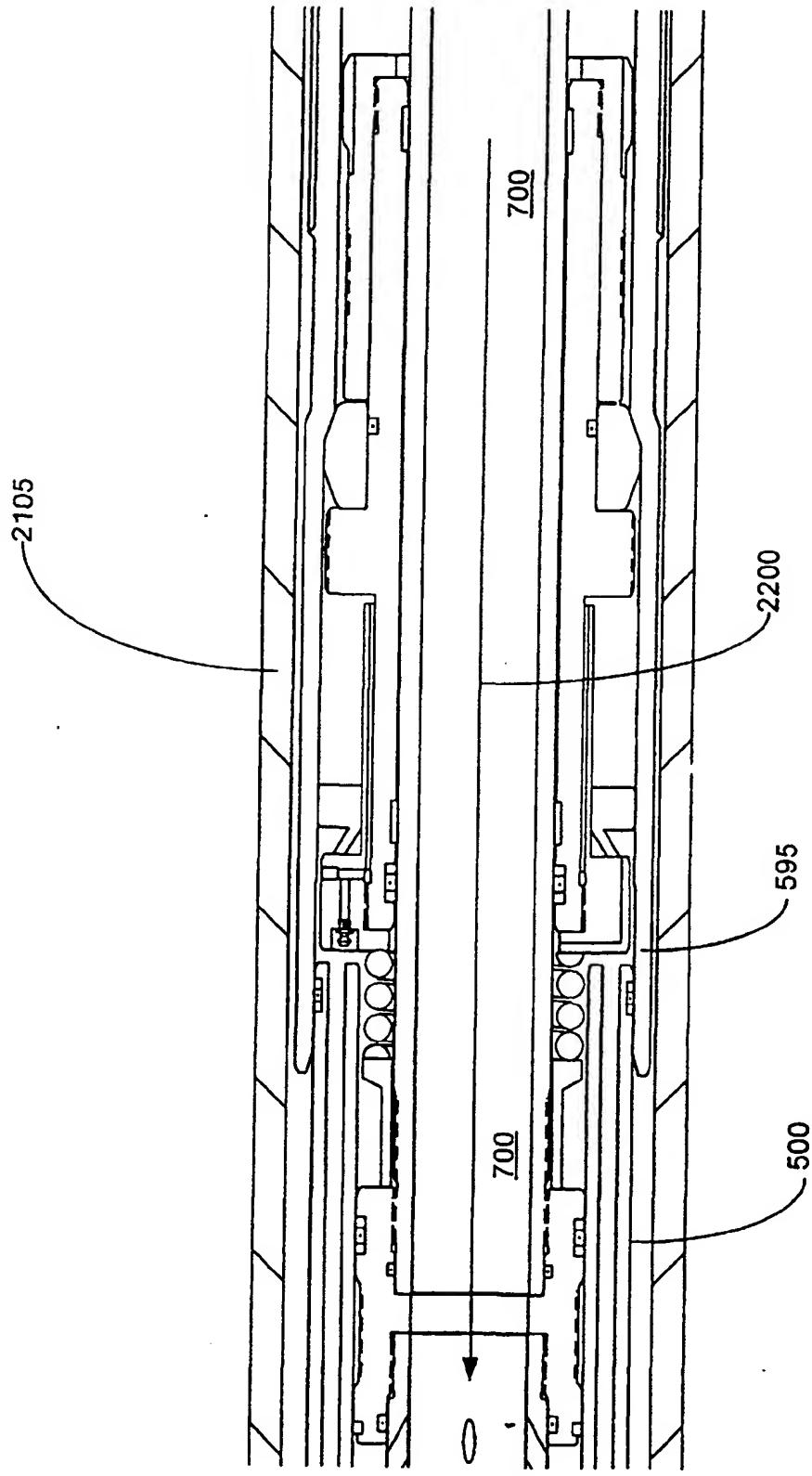


FIGURE 4B

FIGURE 4C

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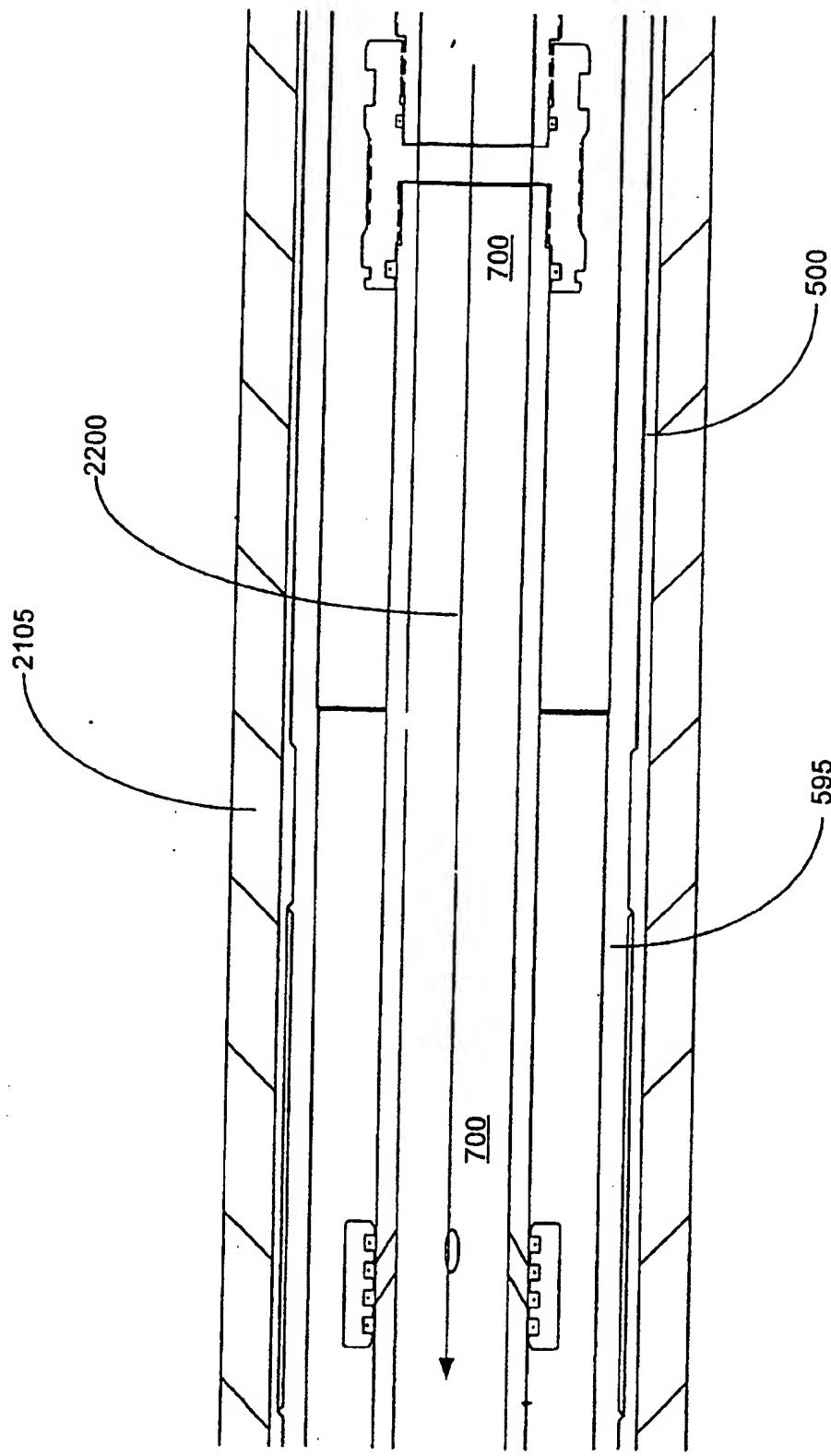


FIGURE 4D

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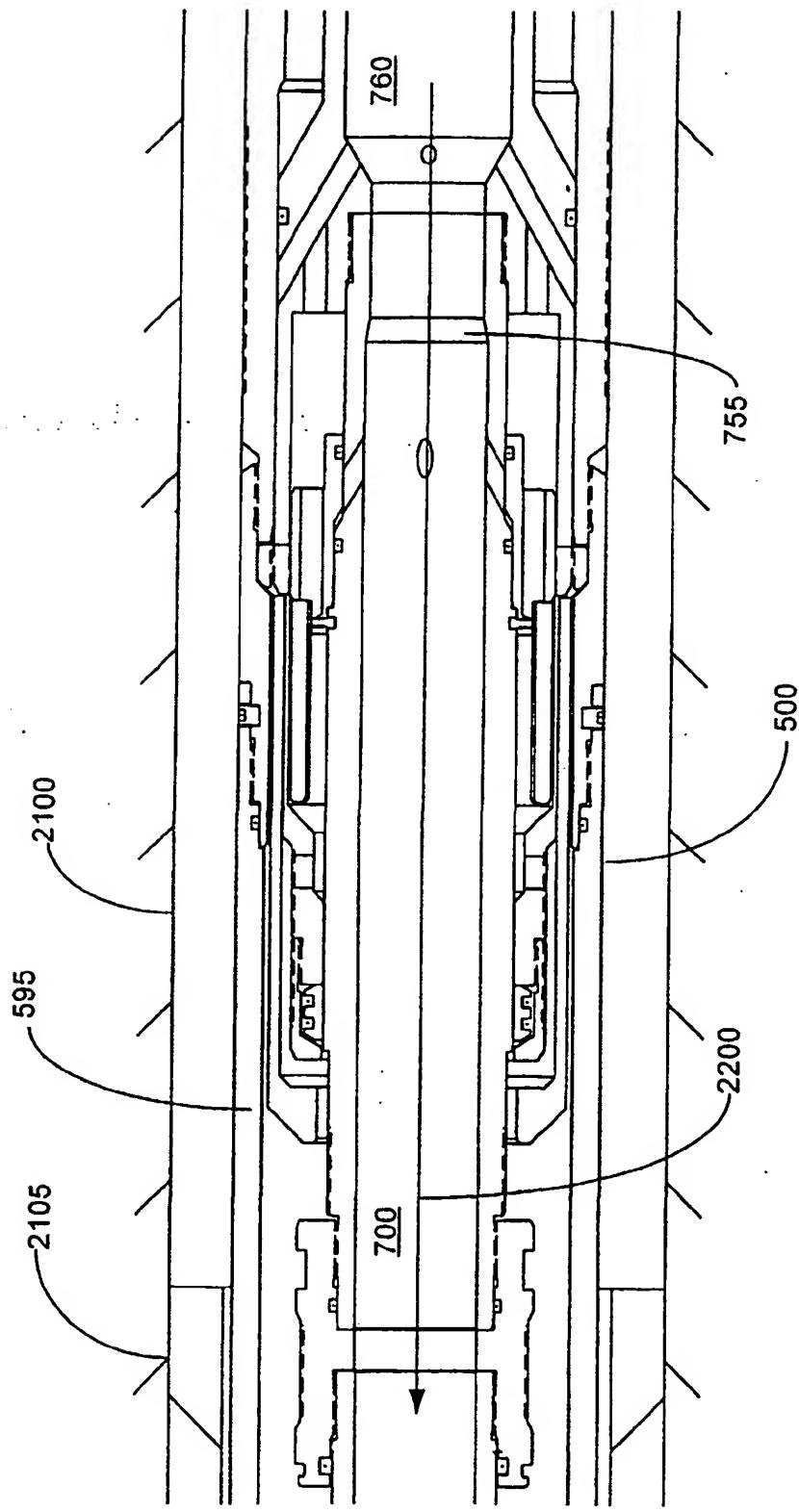


FIGURE 4E

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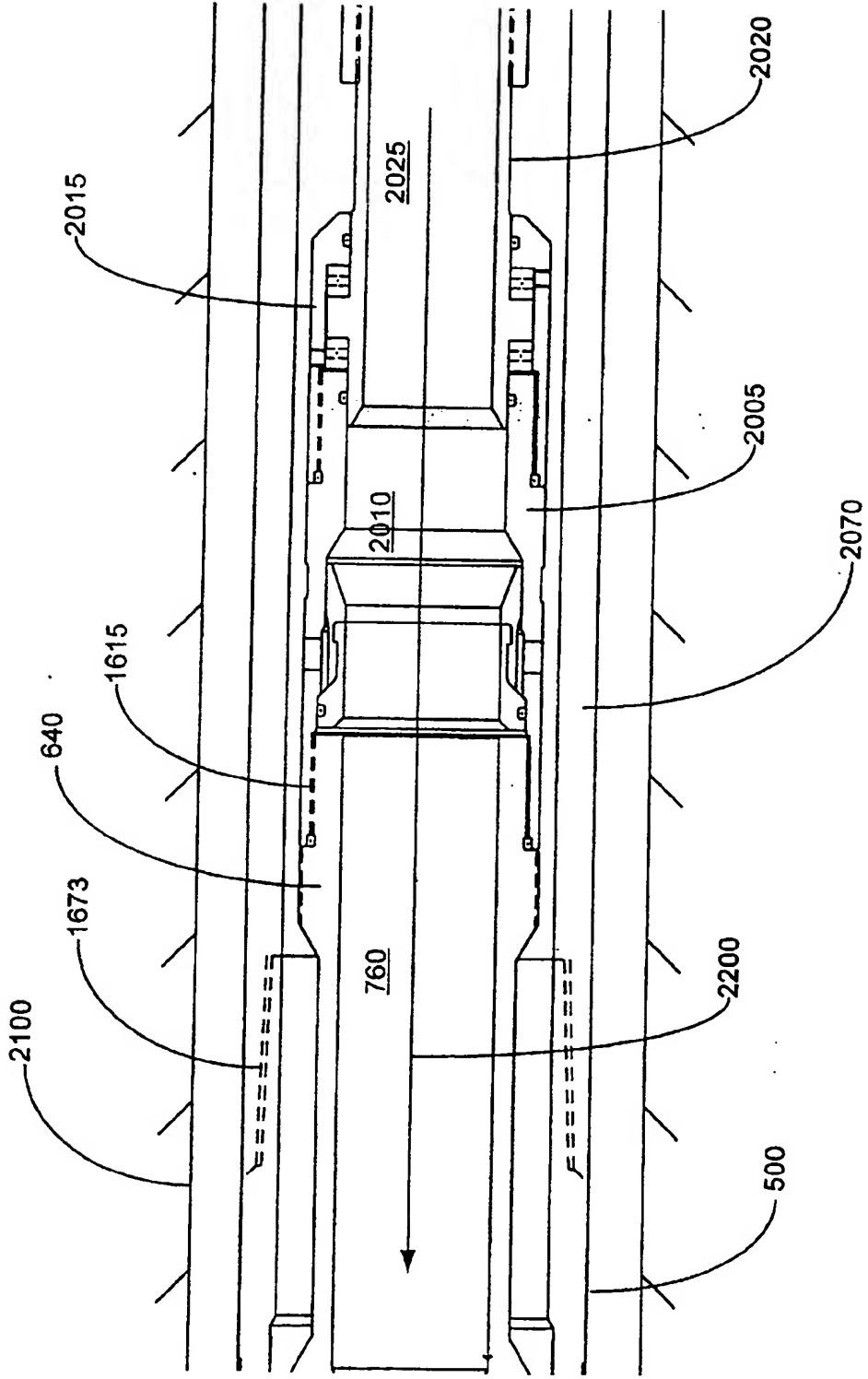


FIGURE 4F

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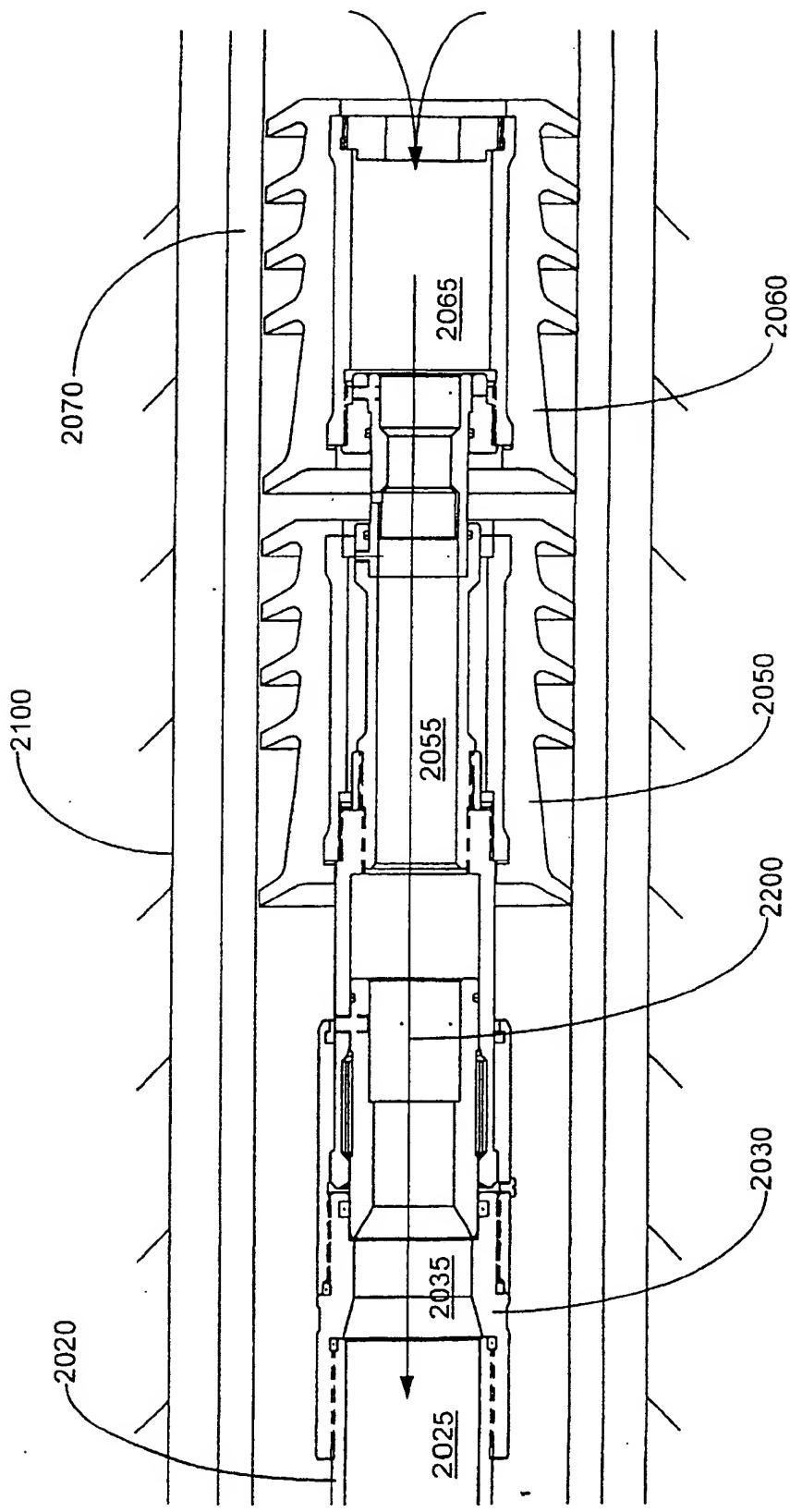


FIGURE 4G

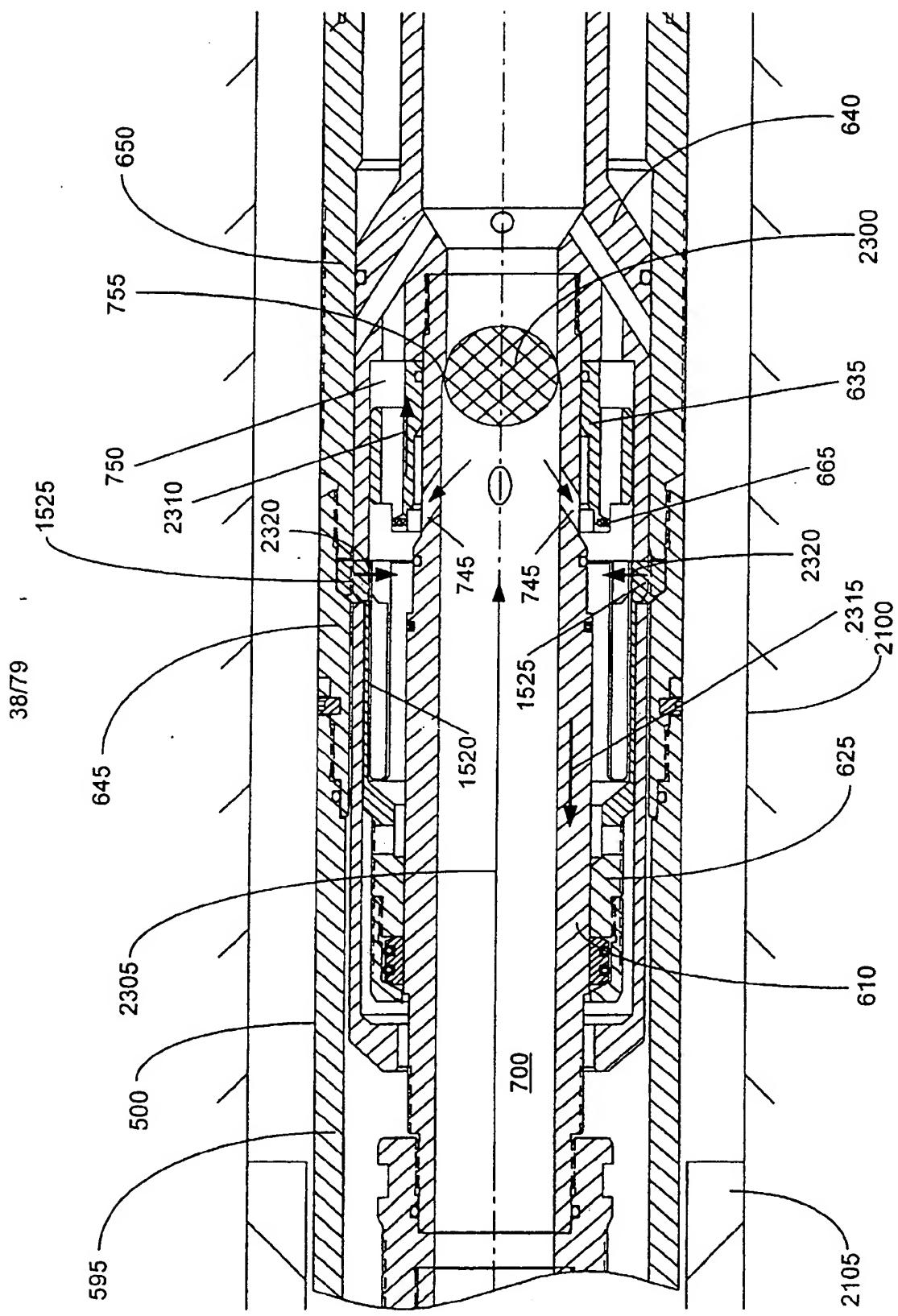


FIGURE 5A

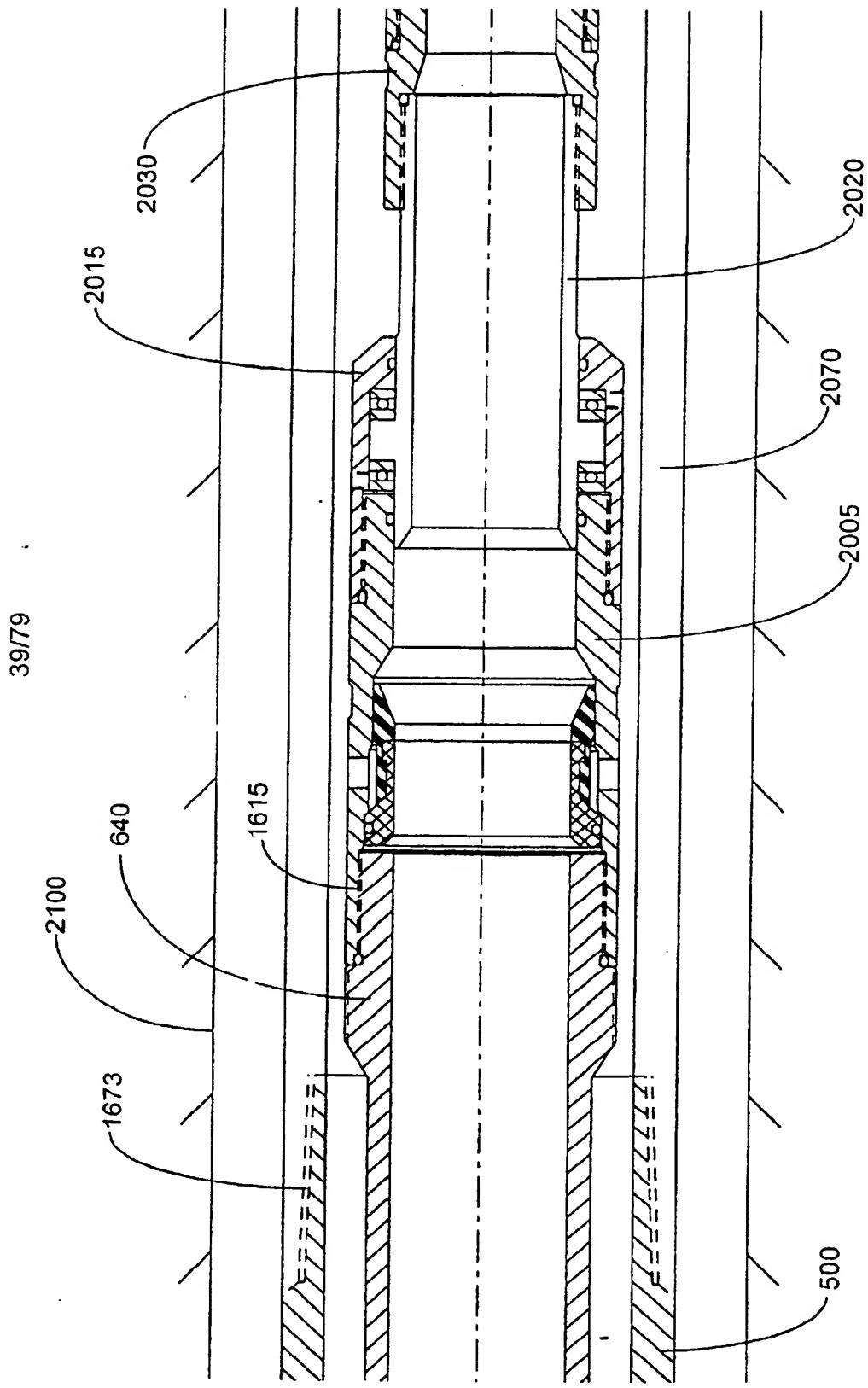


FIGURE 5B

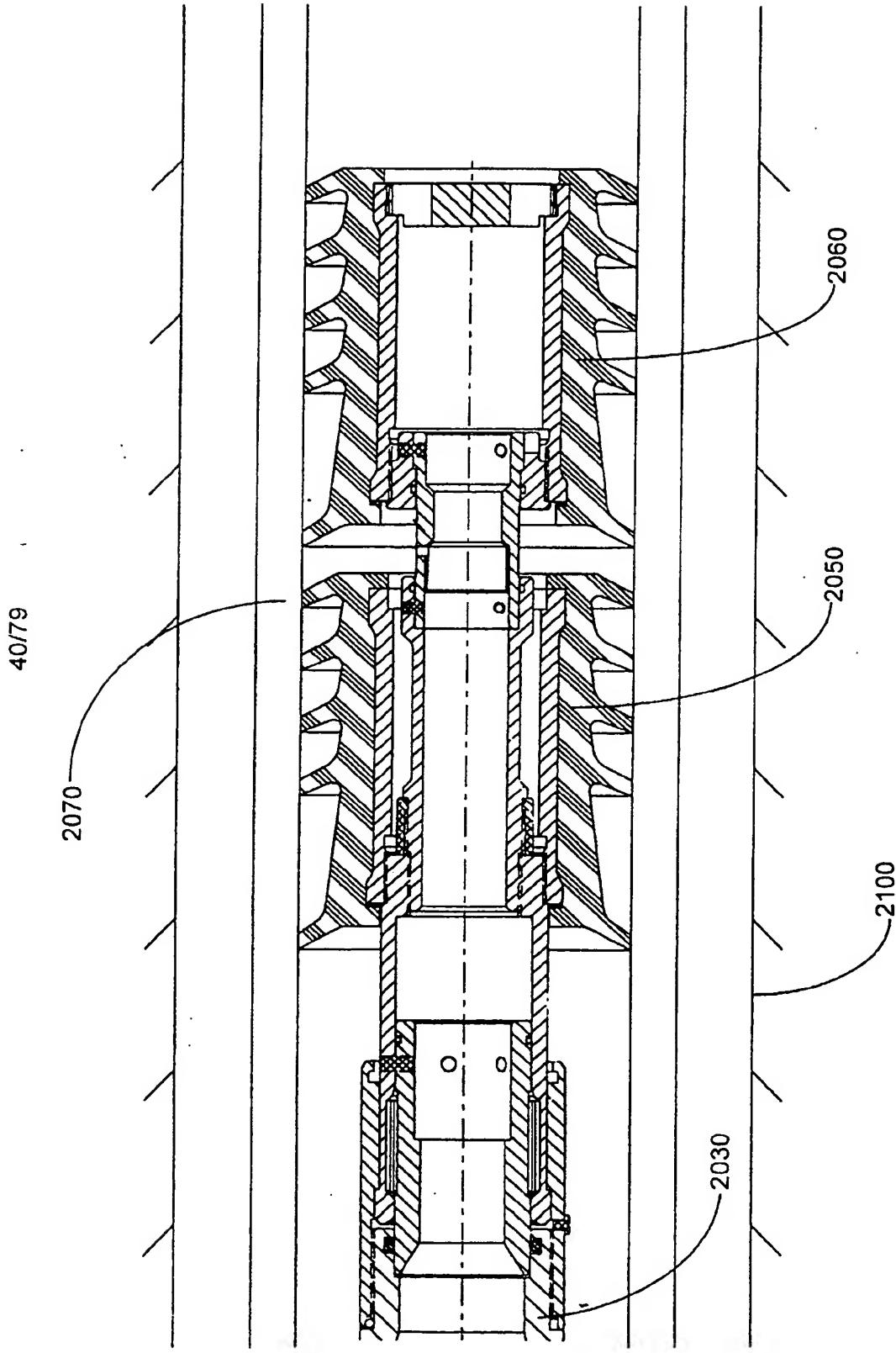


FIGURE 5C

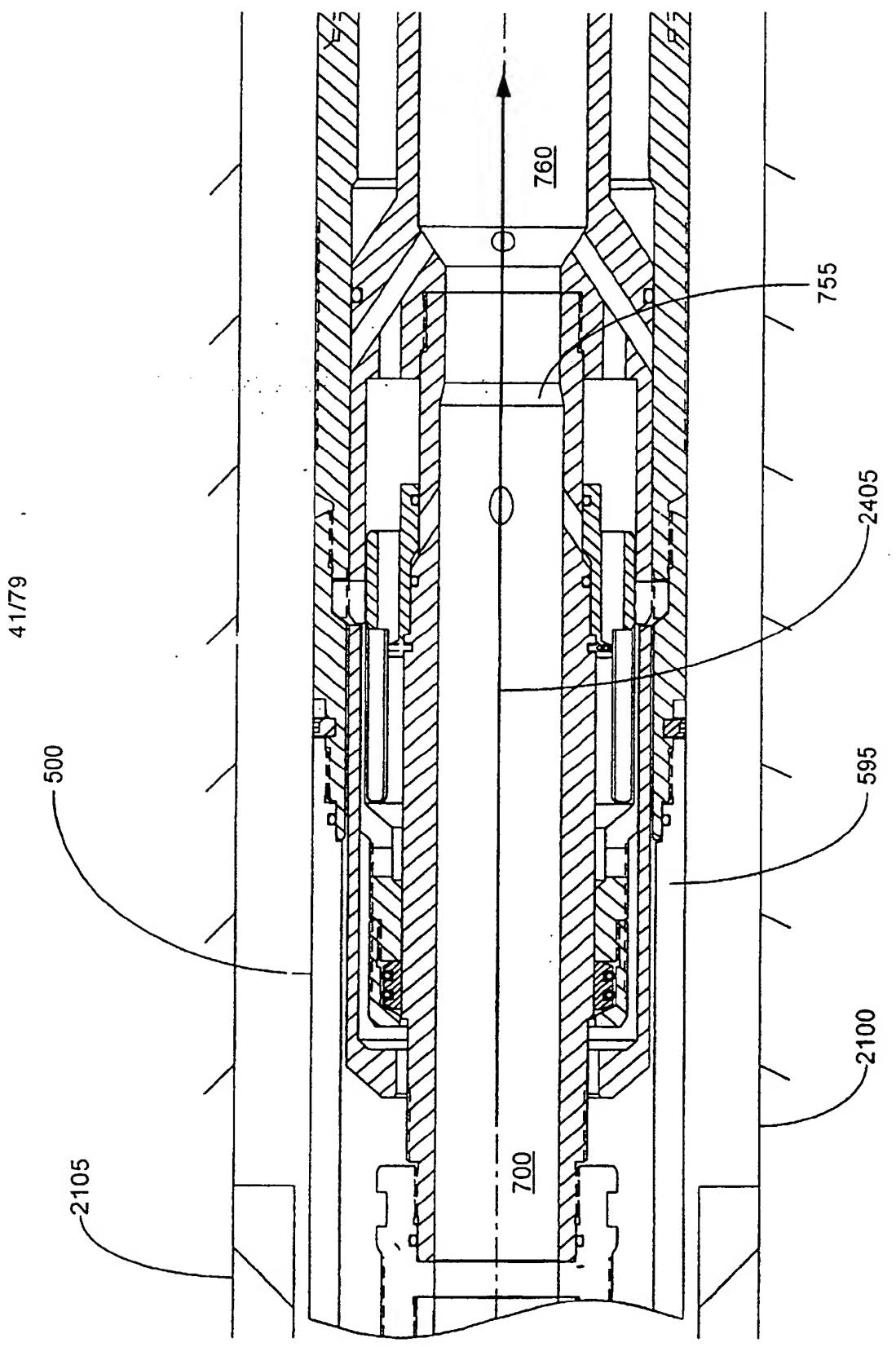


FIGURE 6A

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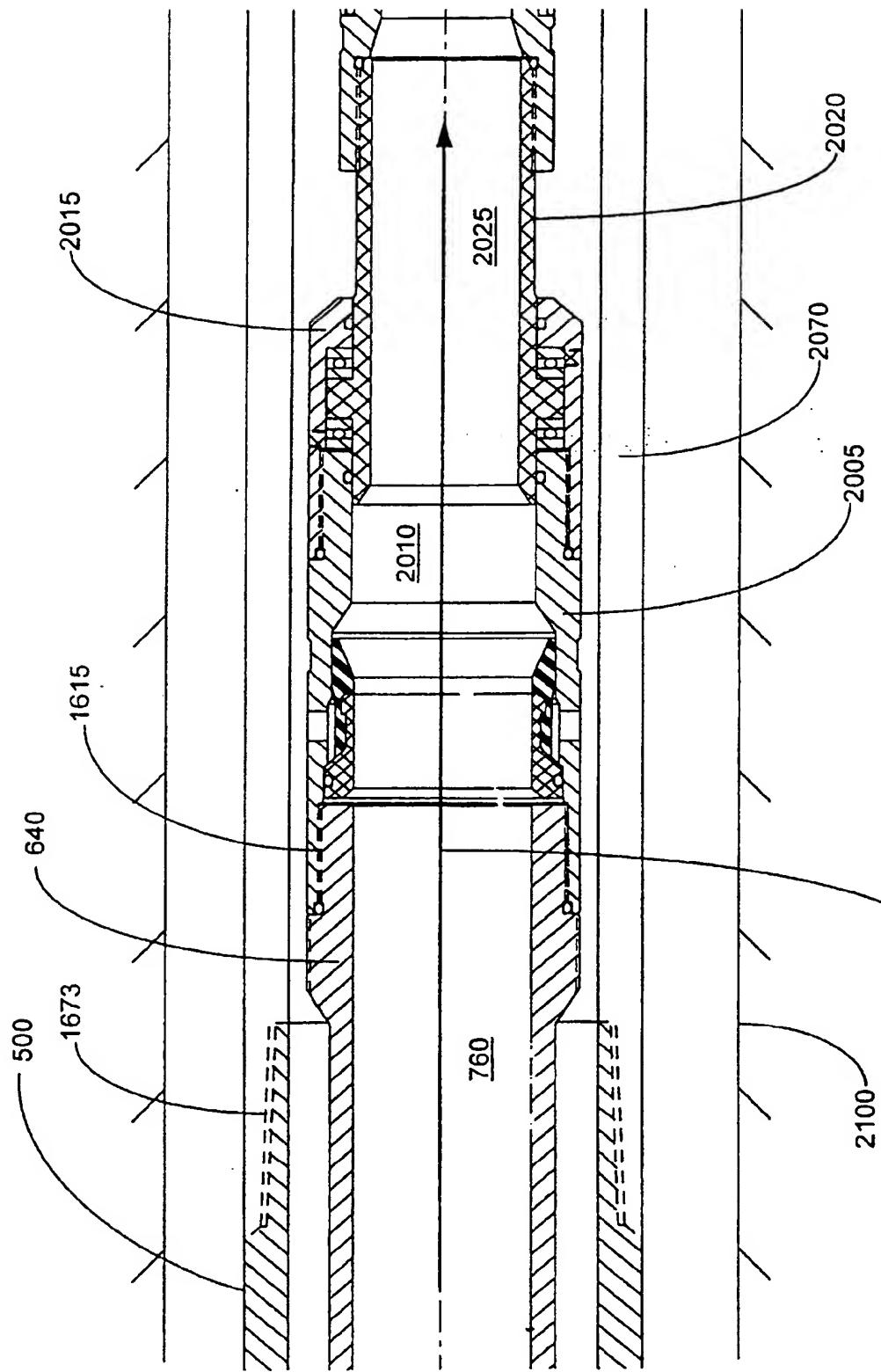


FIGURE 6B

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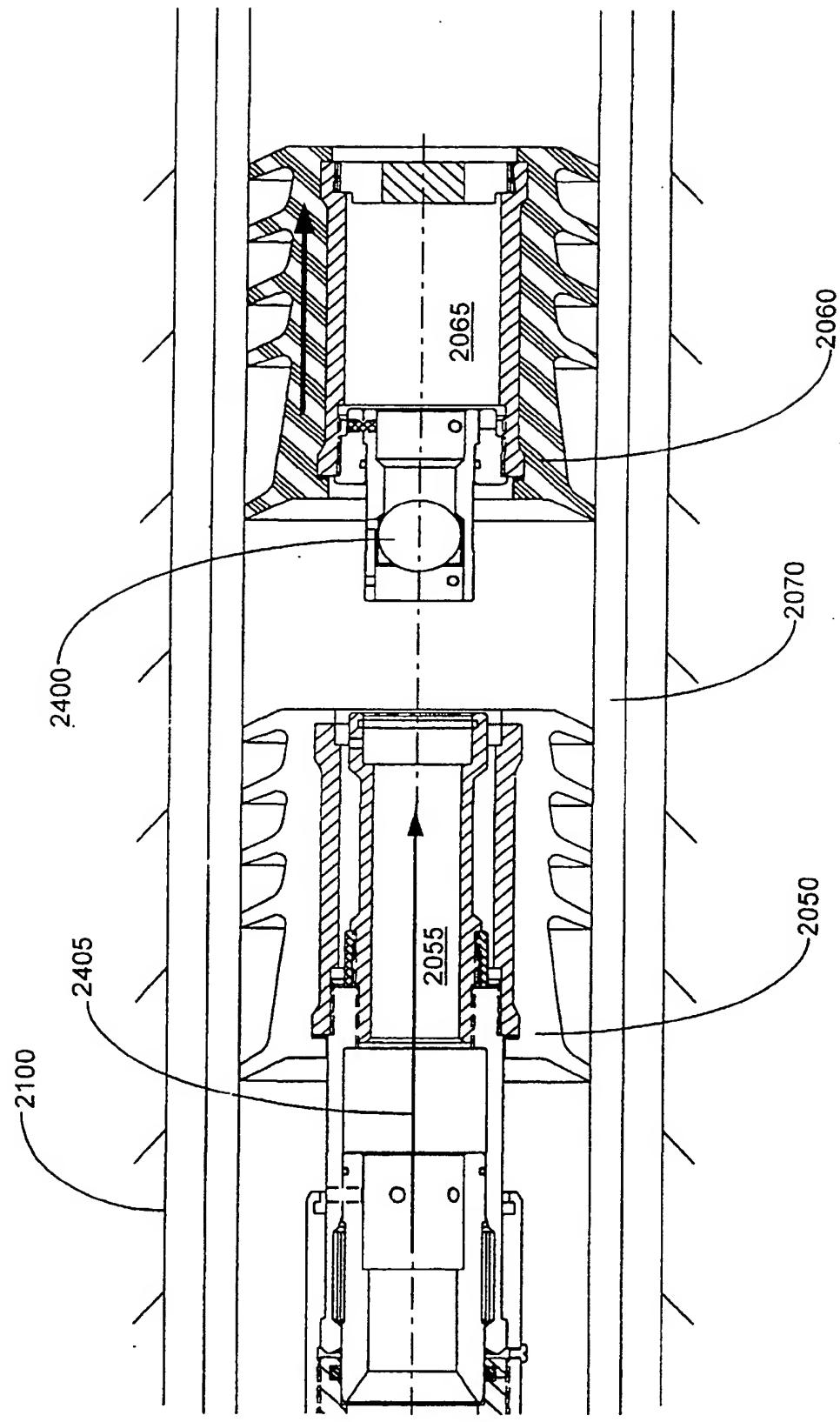


FIGURE 6C

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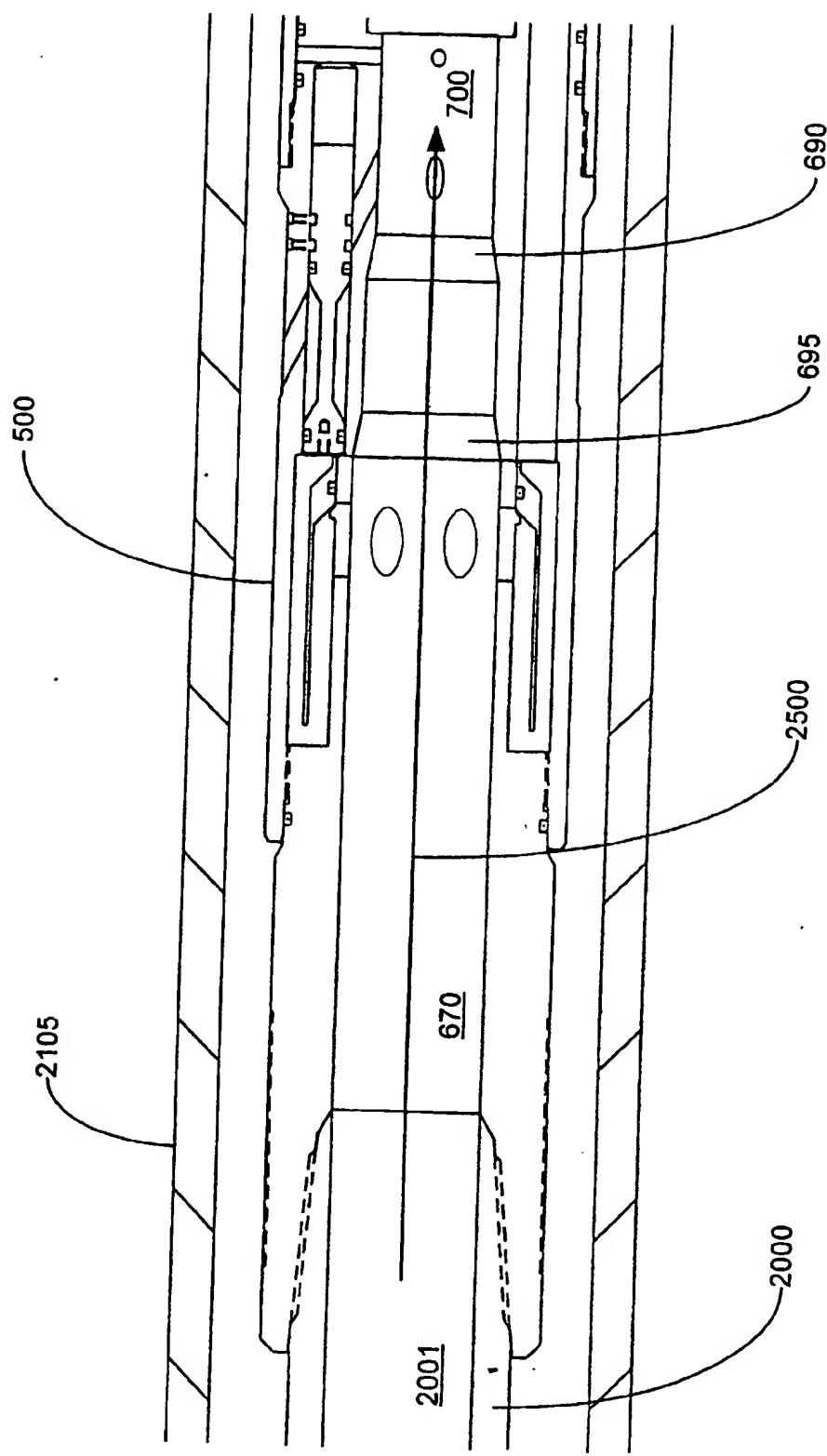


FIGURE 7A

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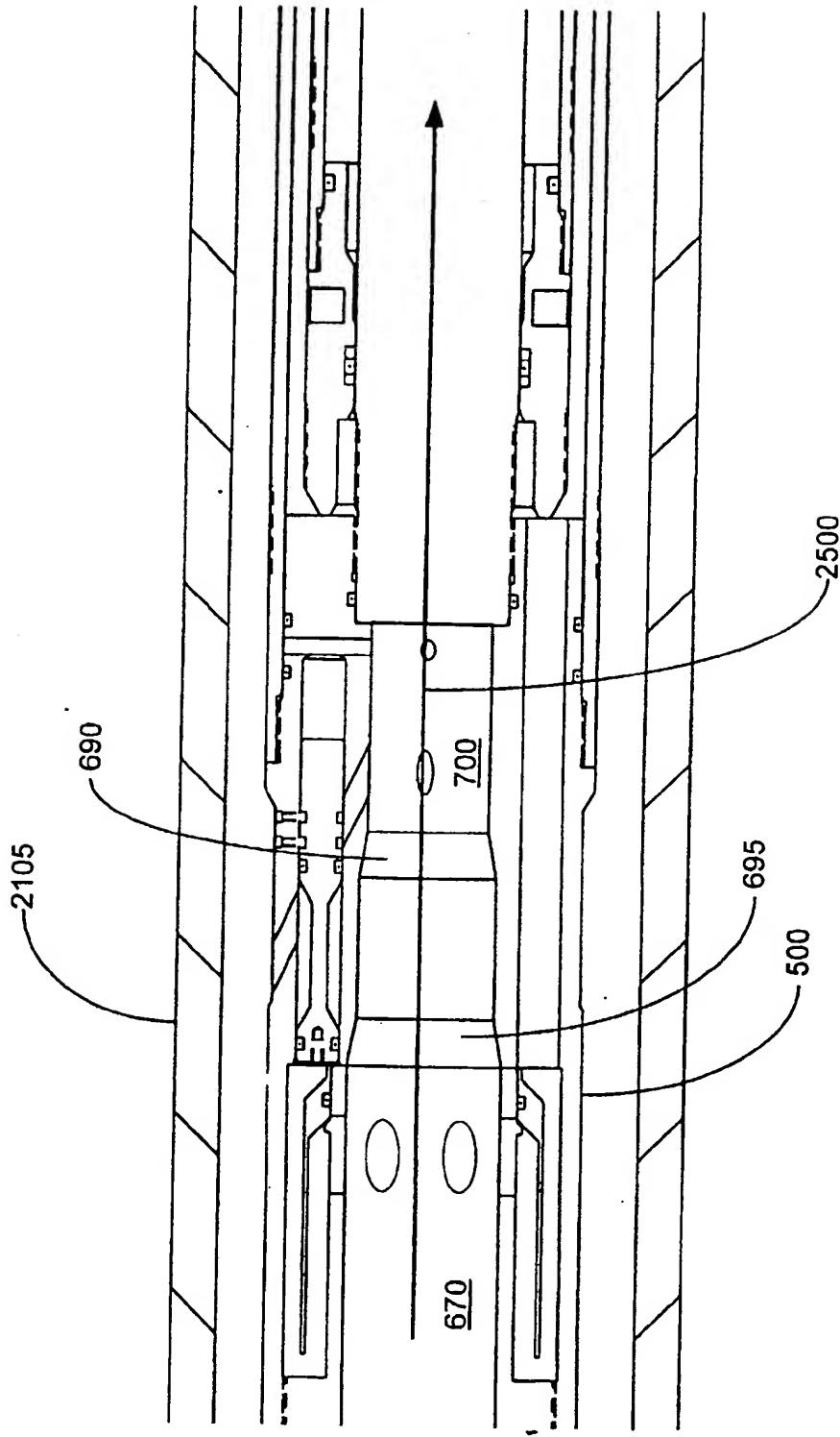
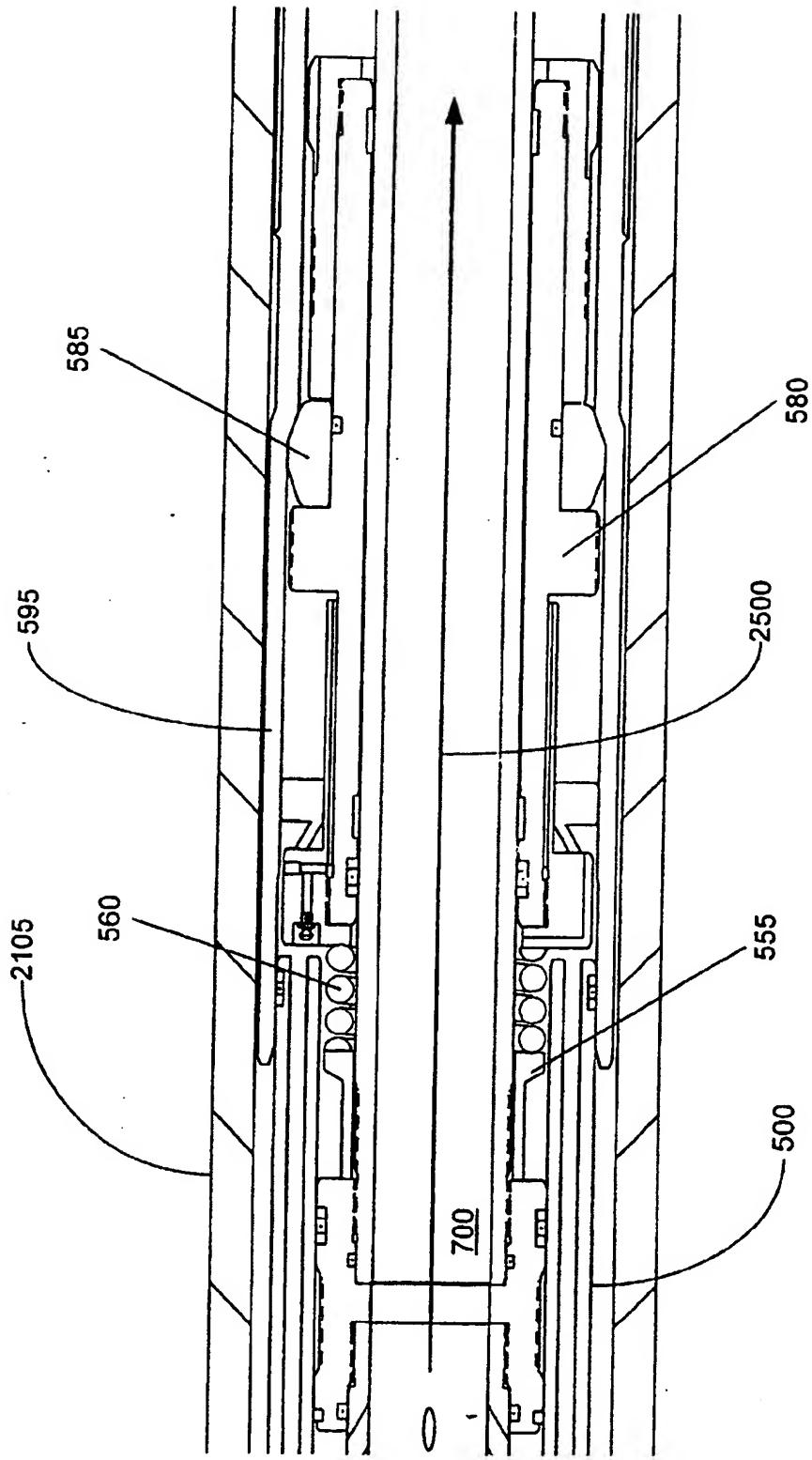


FIGURE 7B

FIGURE 7C

4679



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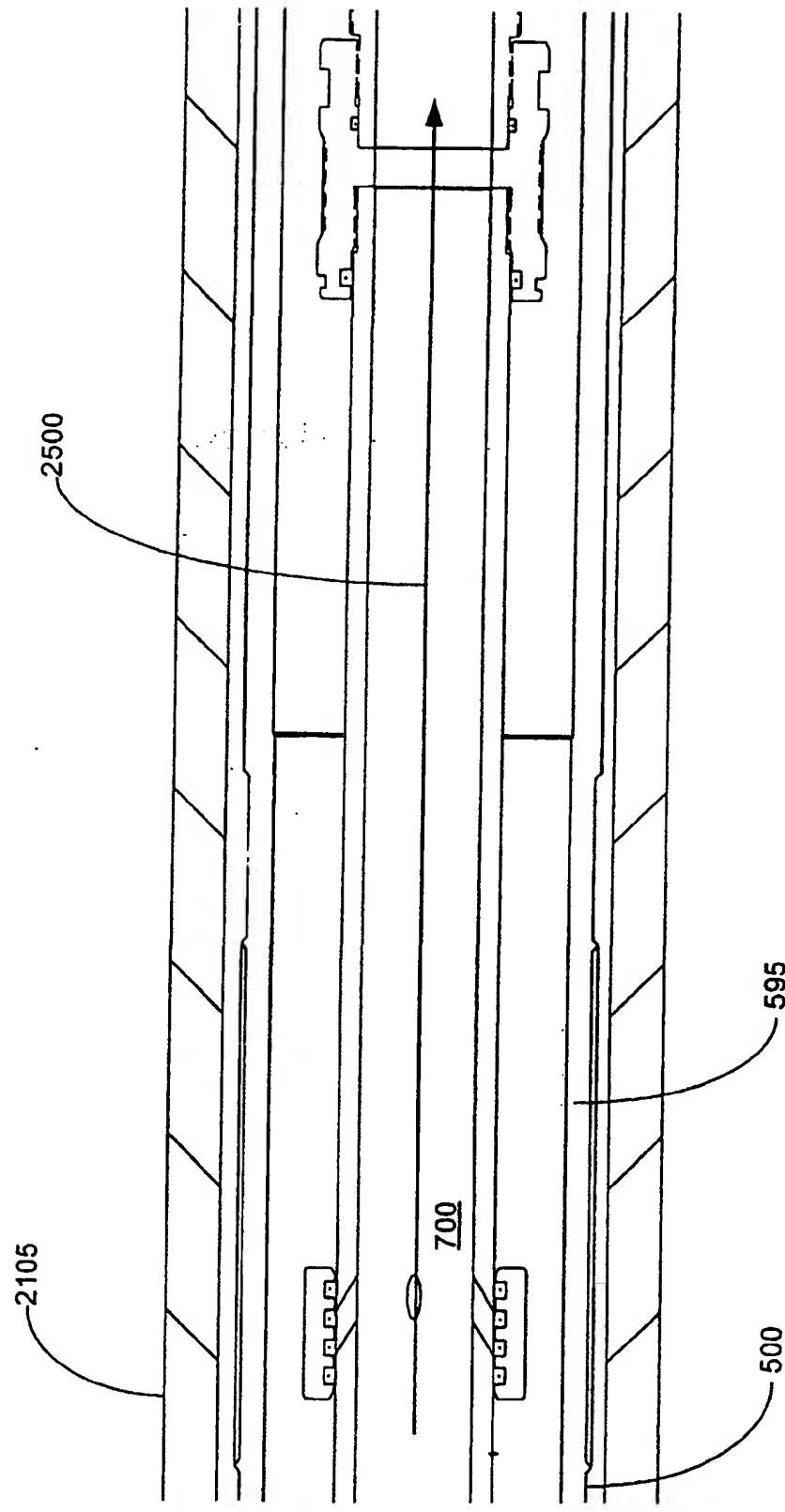


FIGURE 7D

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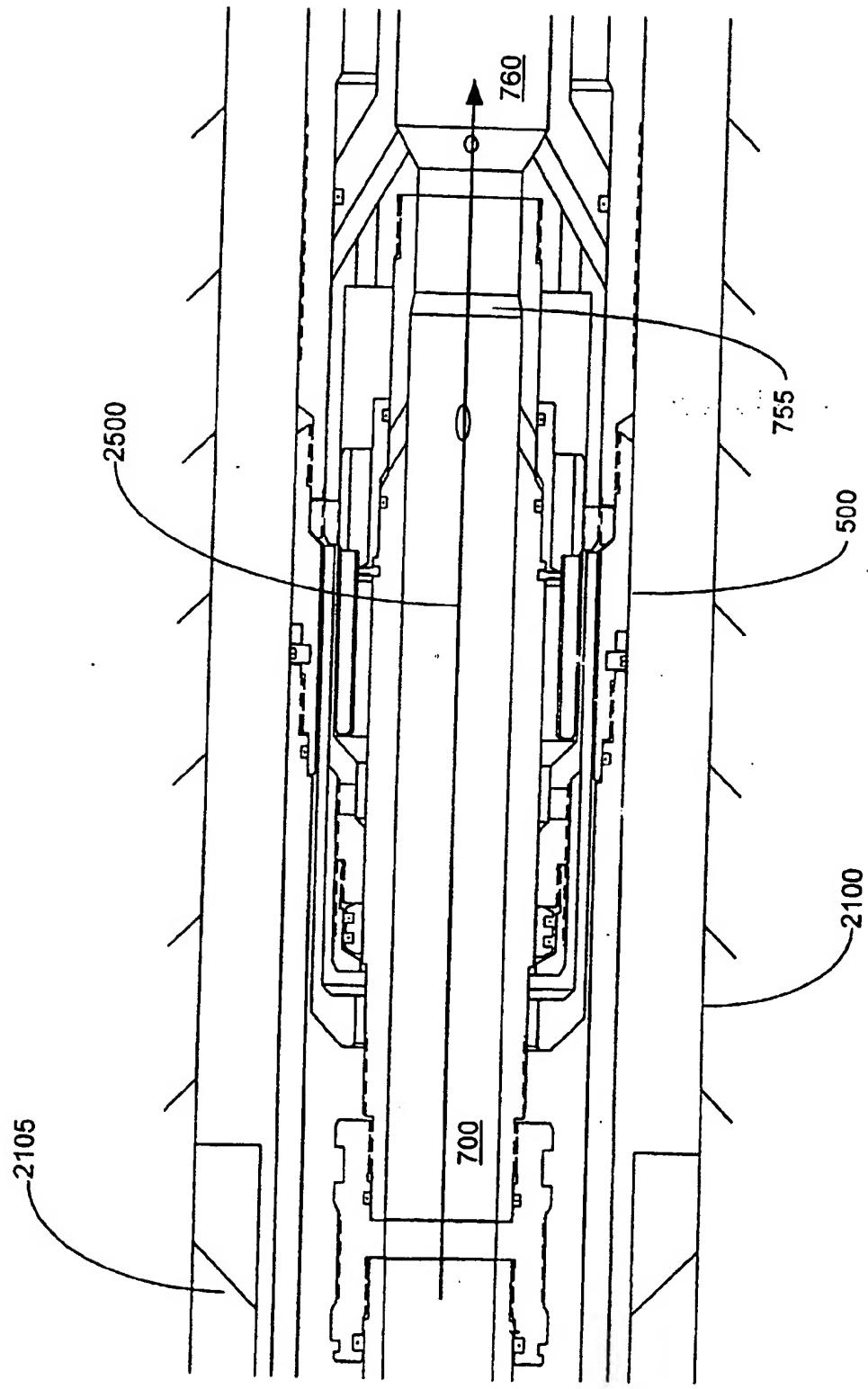


FIGURE 7E

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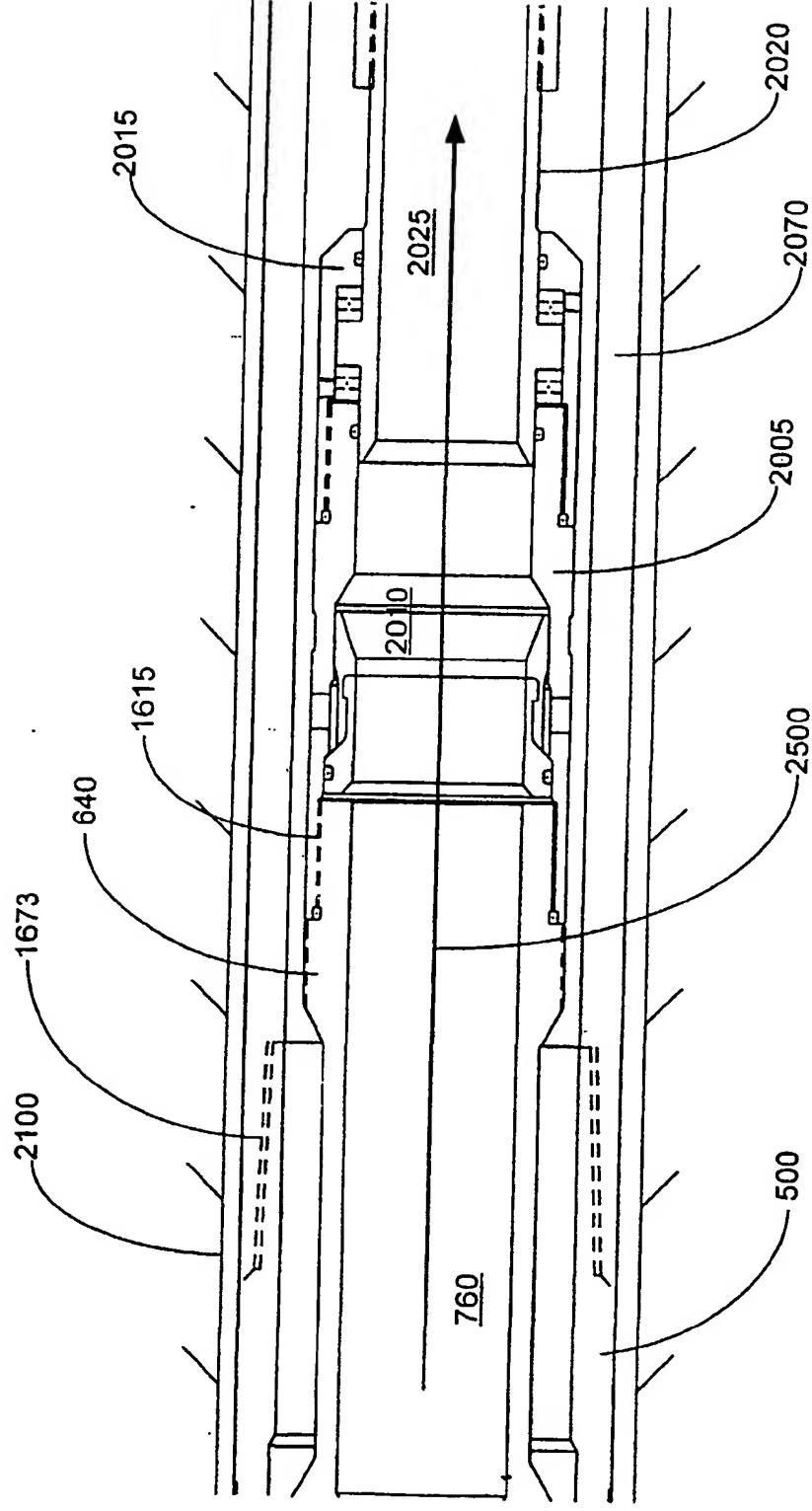


FIGURE 7F

FIGURE 7G

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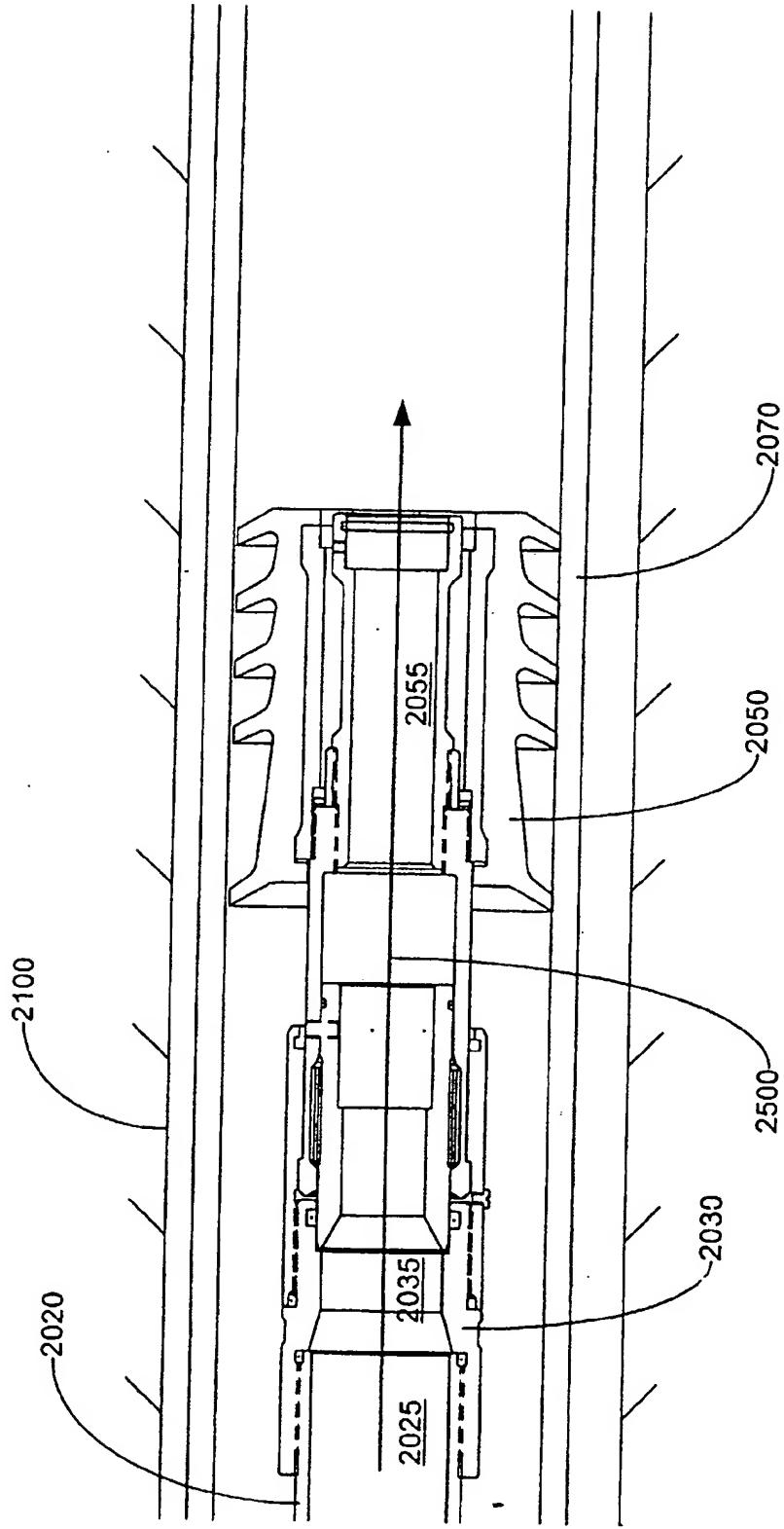
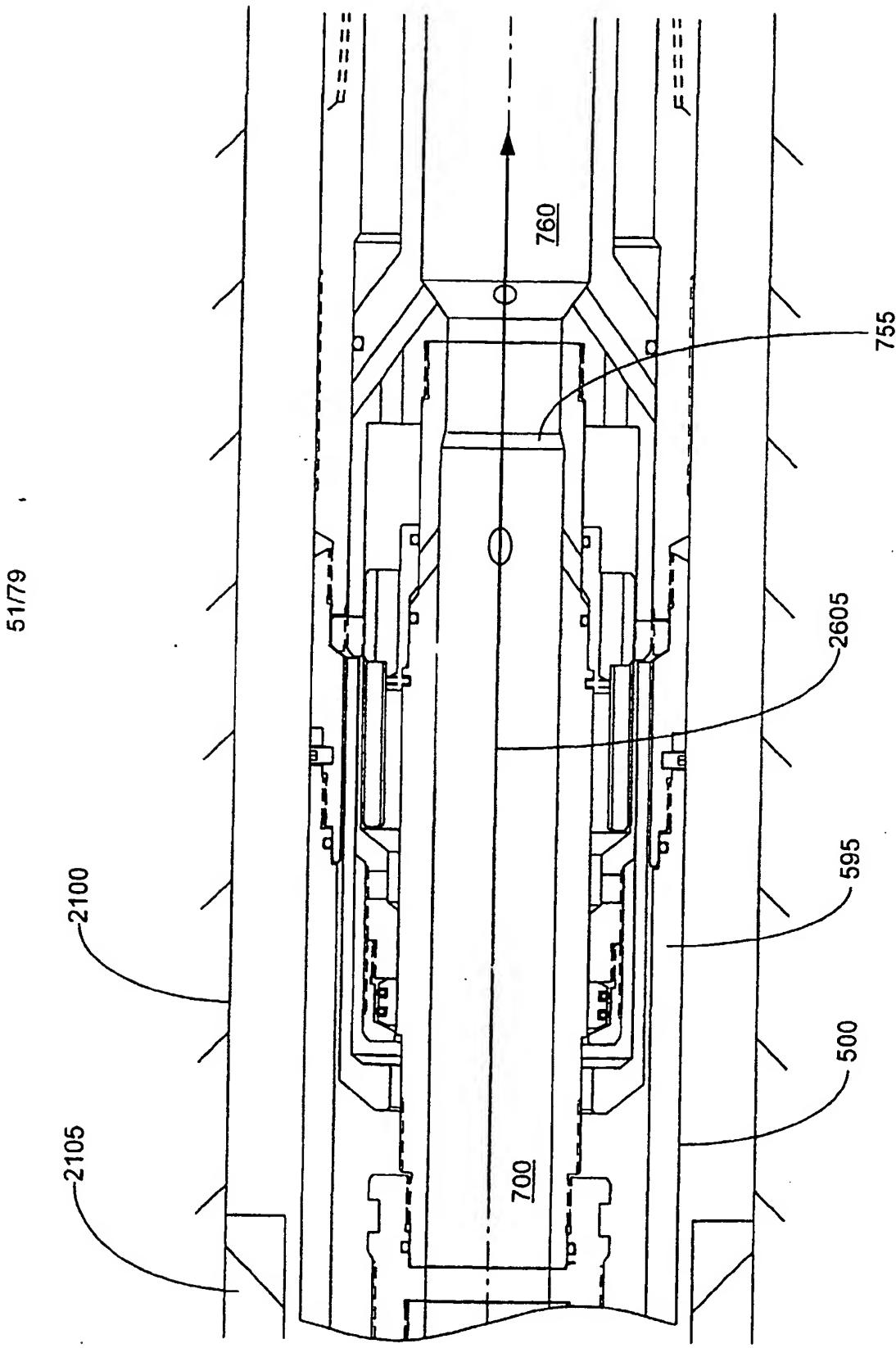


FIGURE 8A



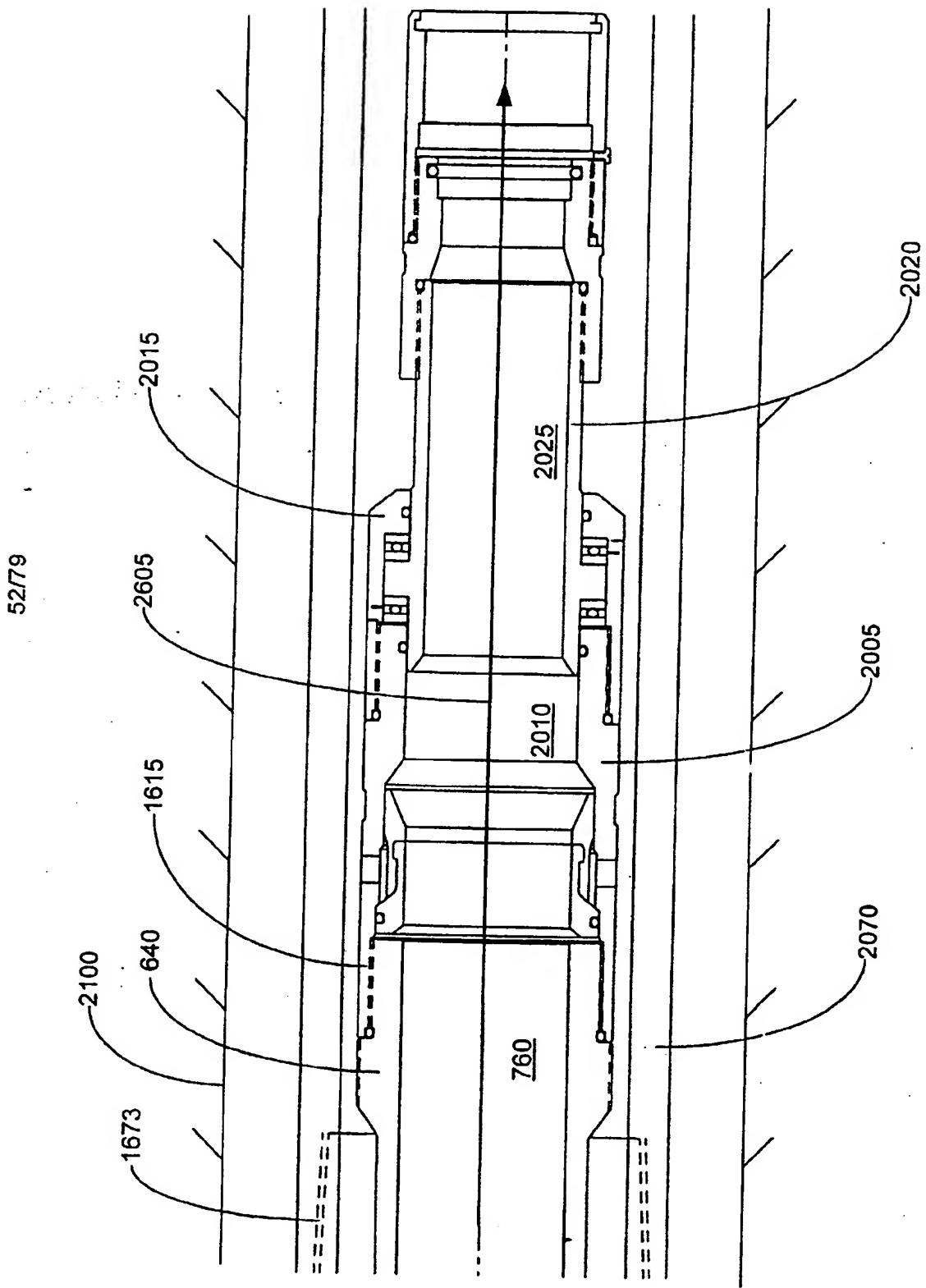


FIGURE 8B

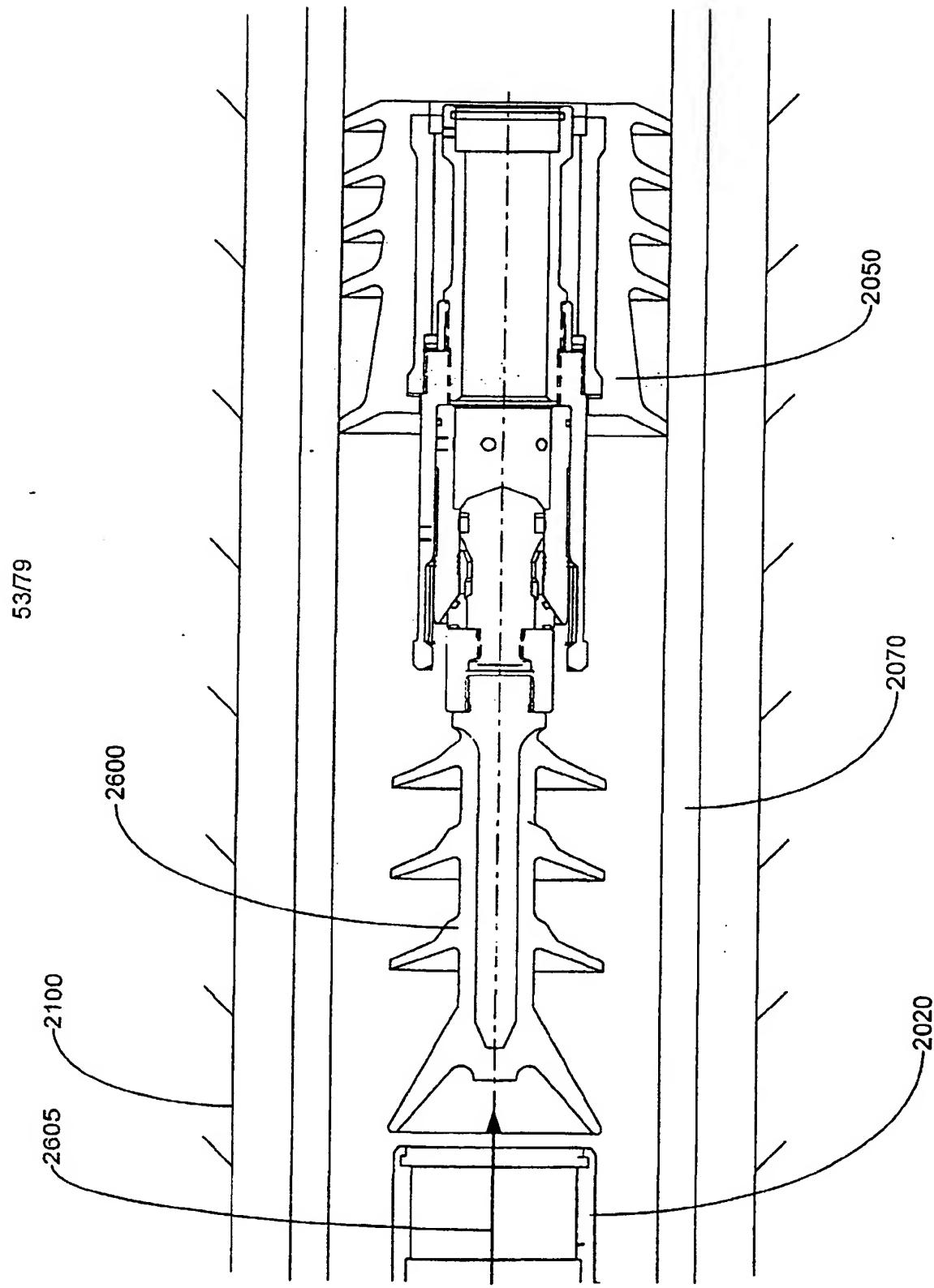
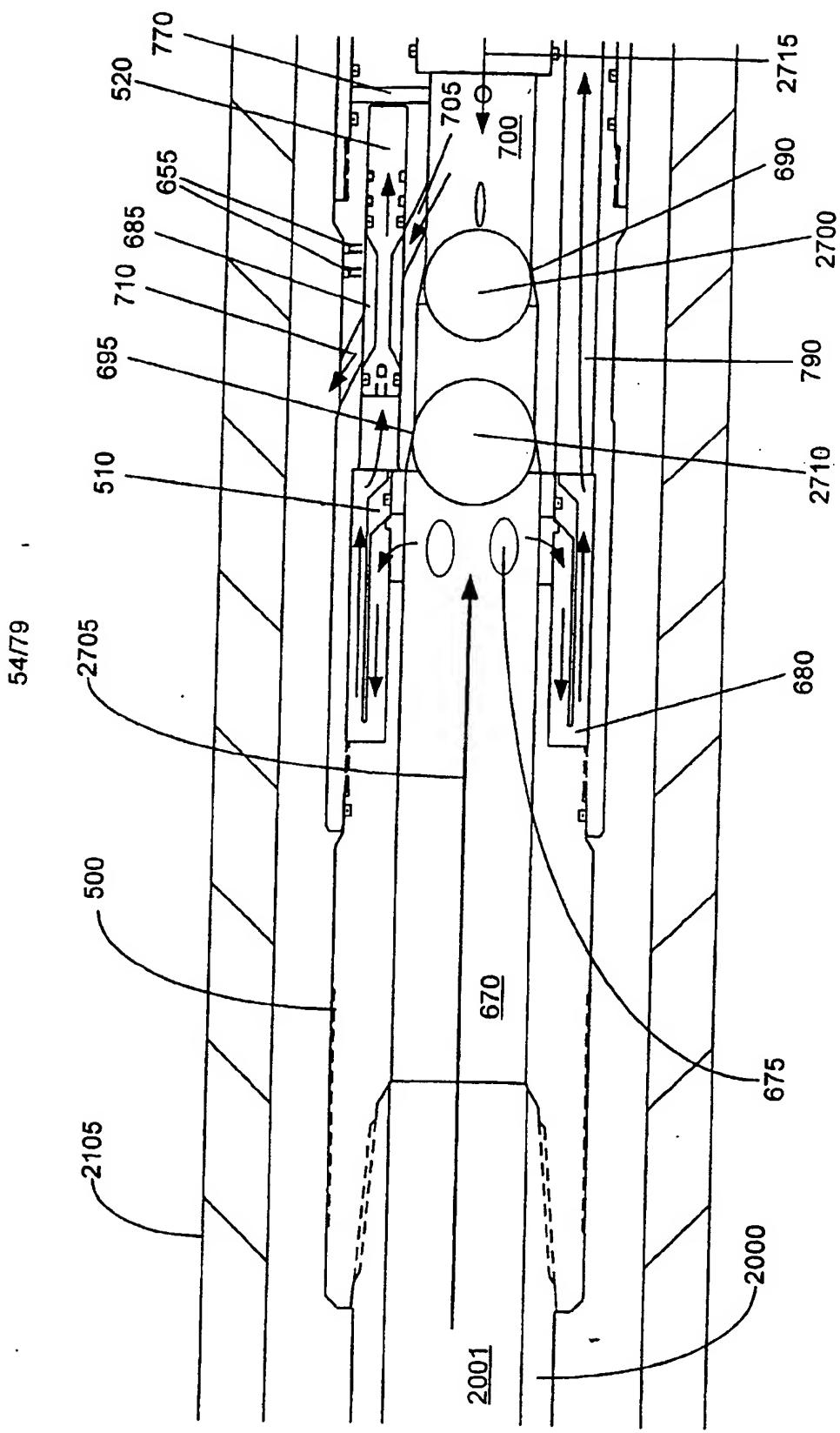


FIGURE 8C

FIGURE 9A



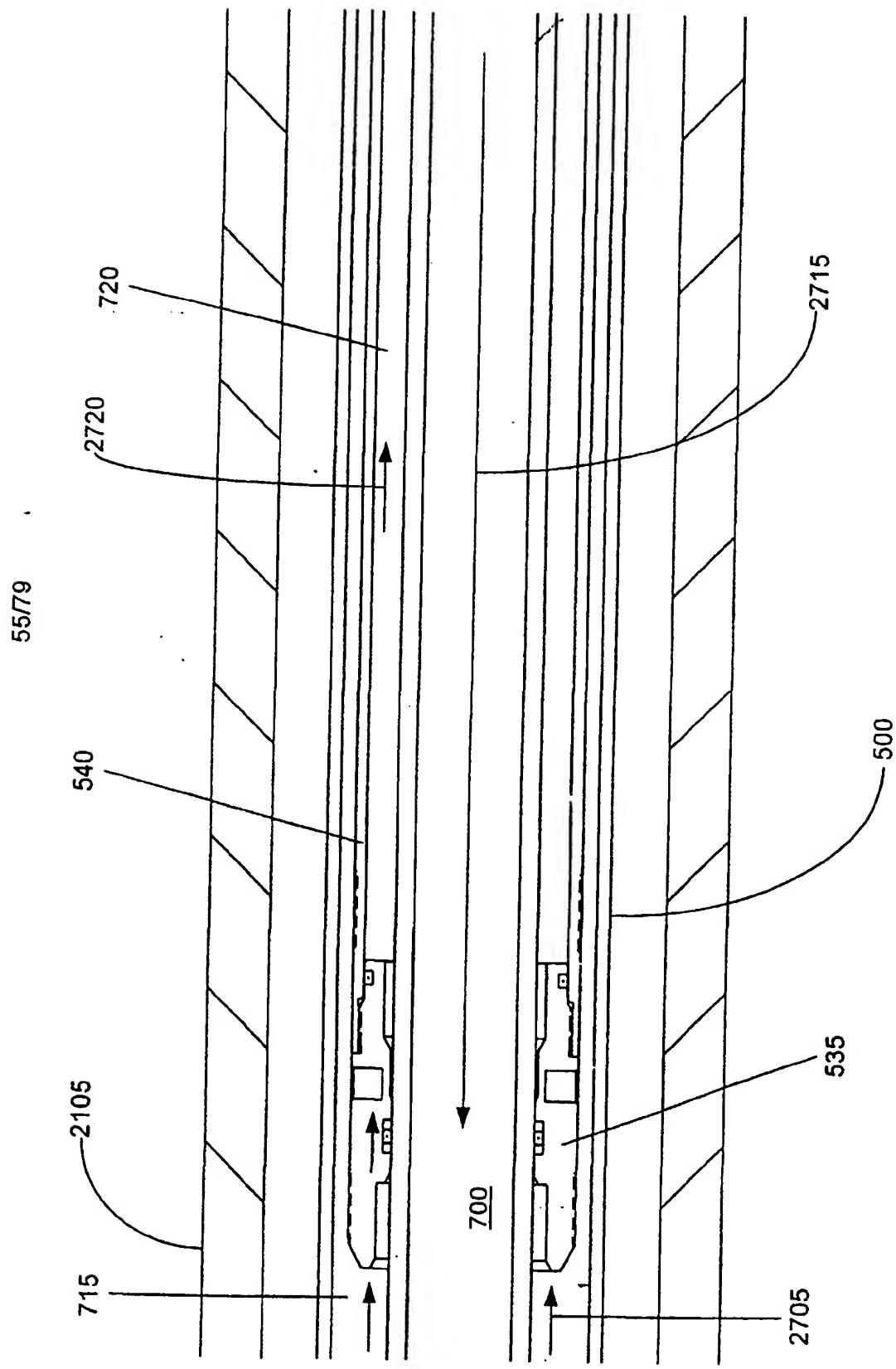
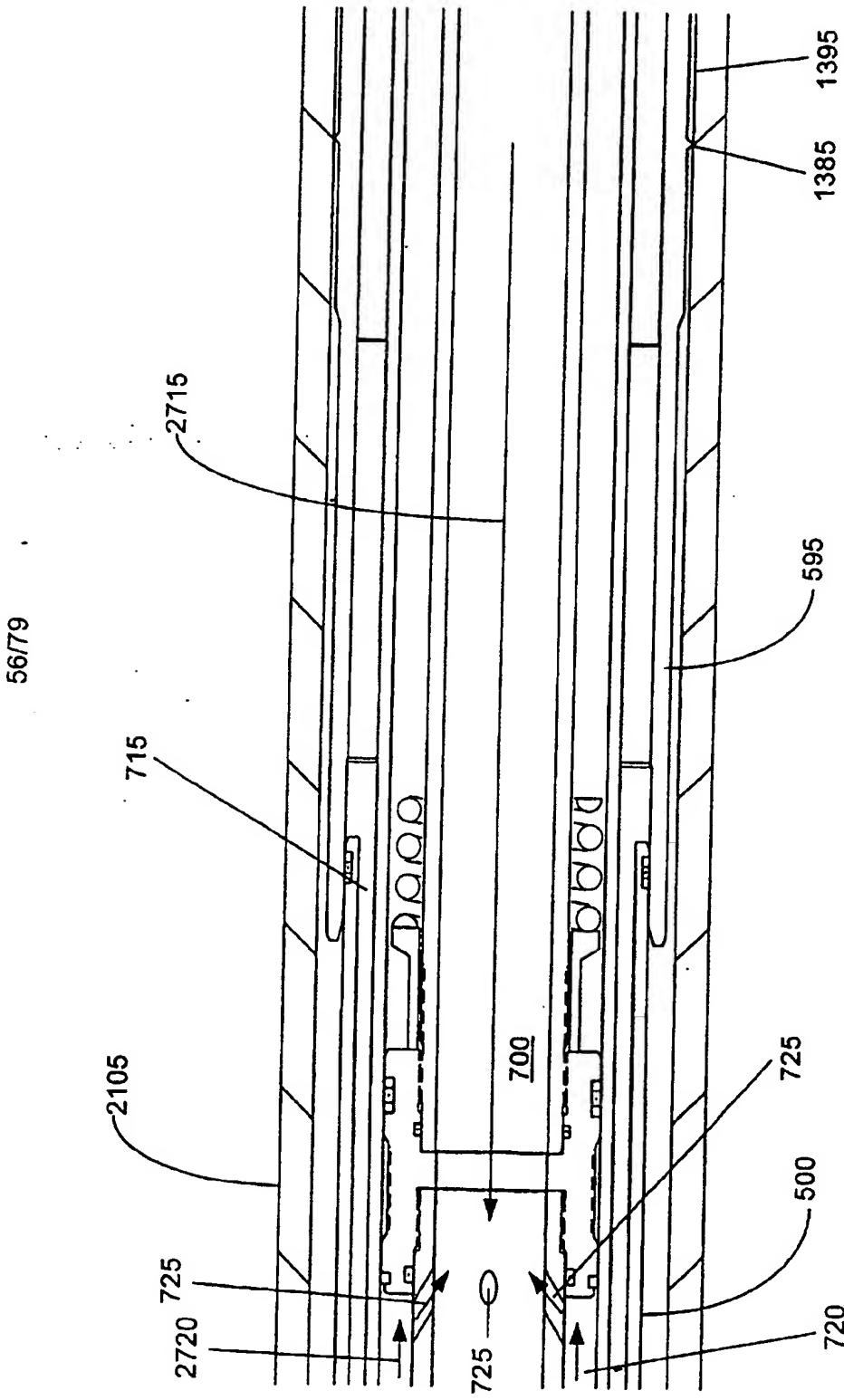


FIGURE 9B

FIGURE 9C



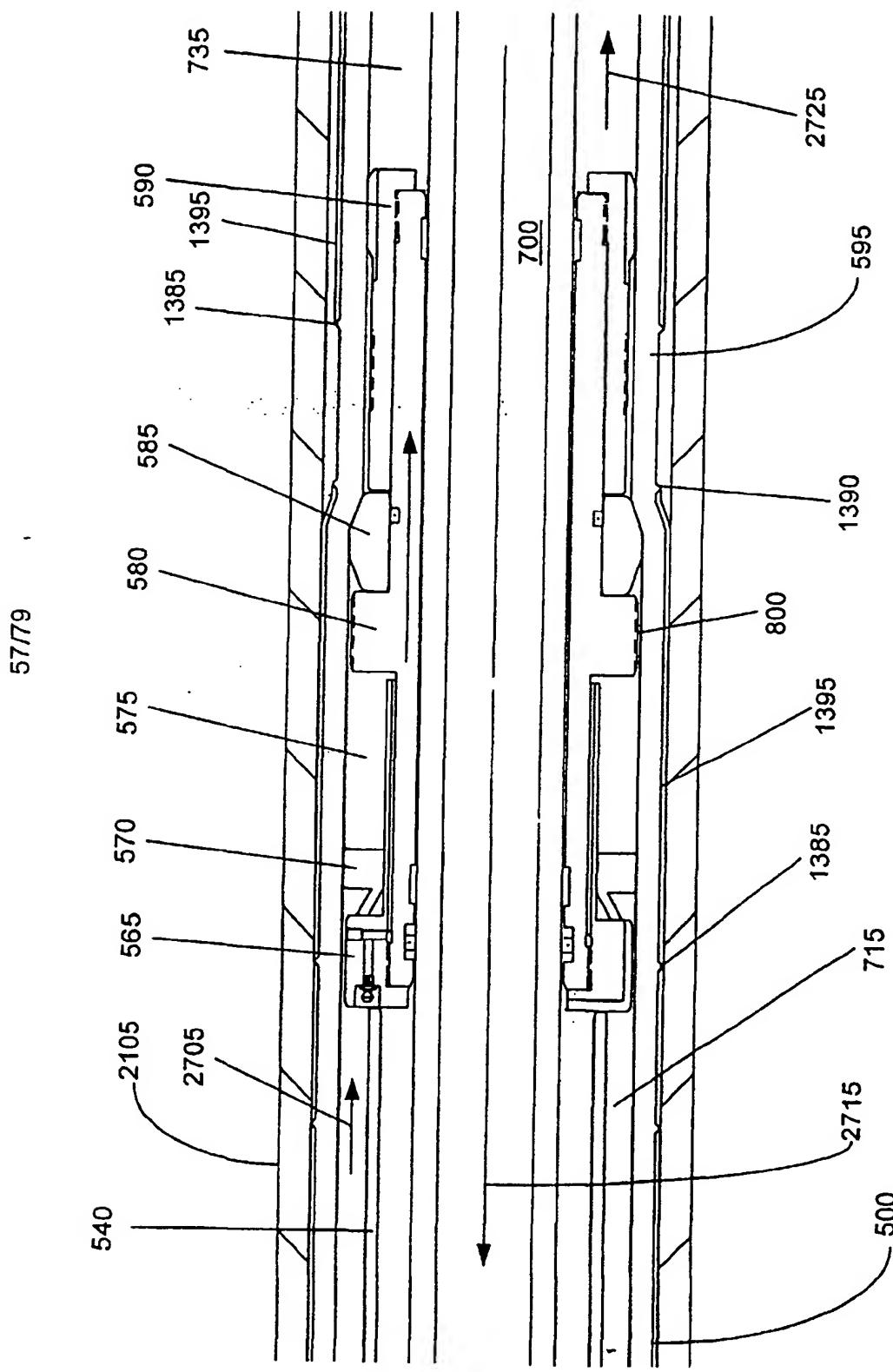


FIGURE 9D

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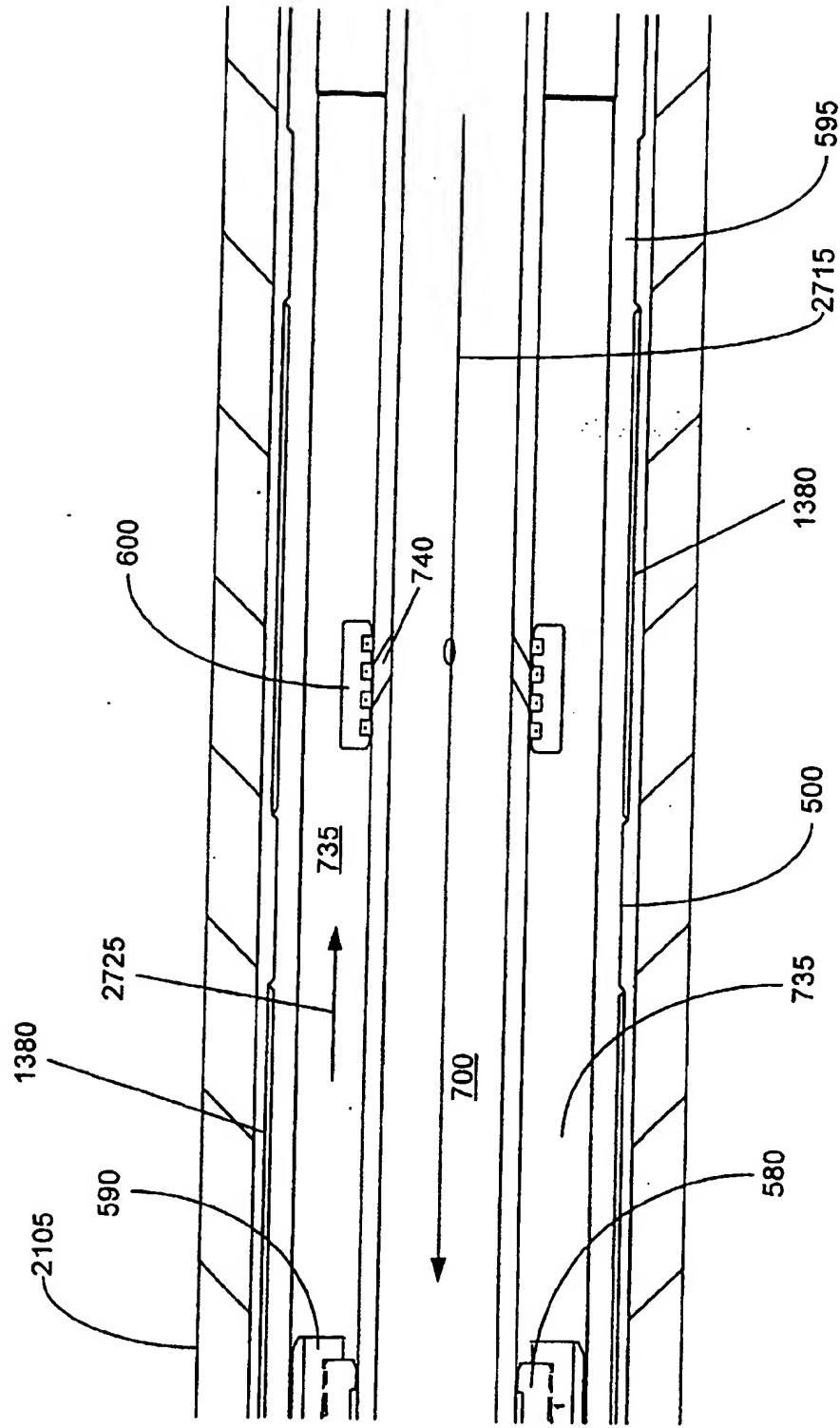


FIGURE 9E

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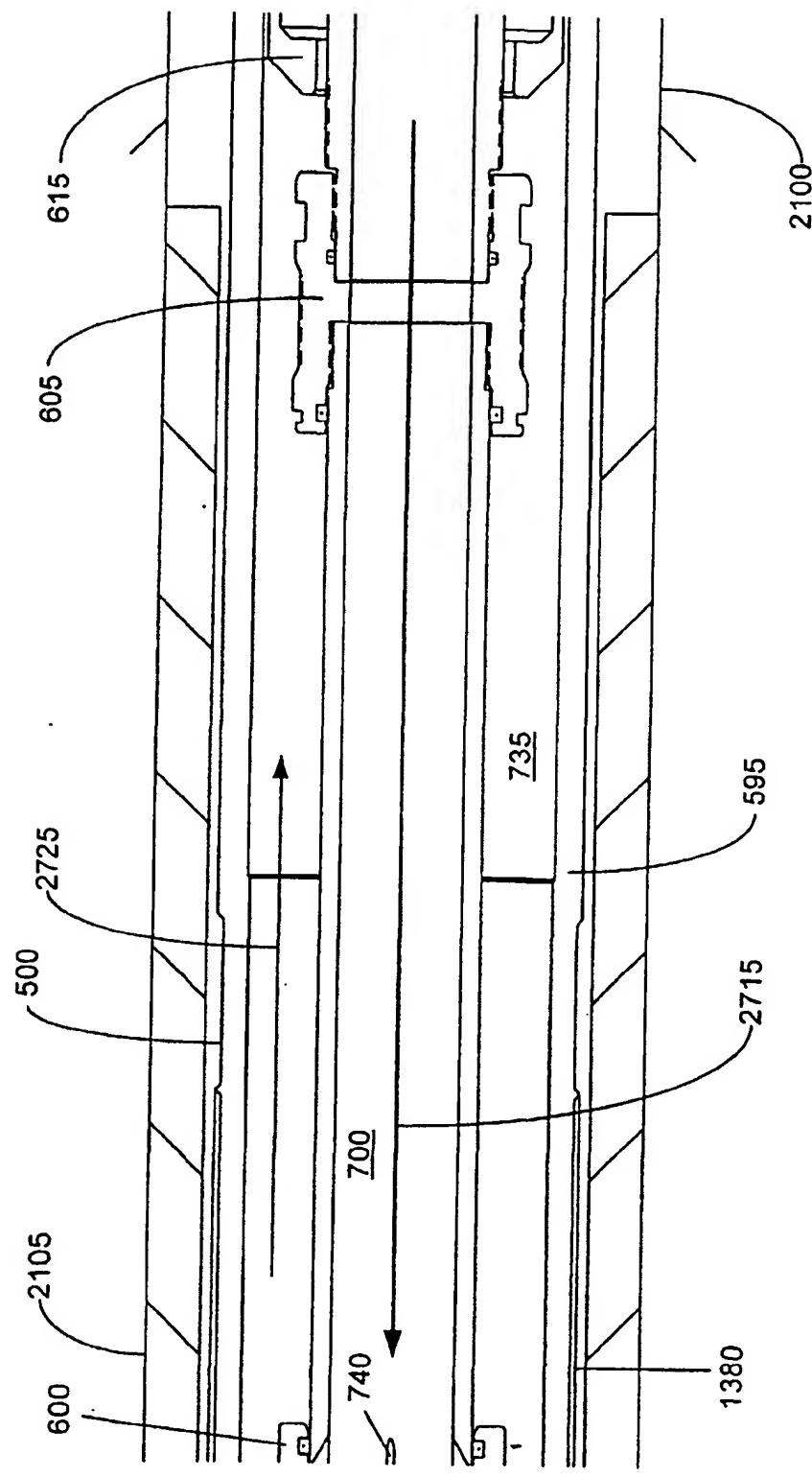


FIGURE 9F

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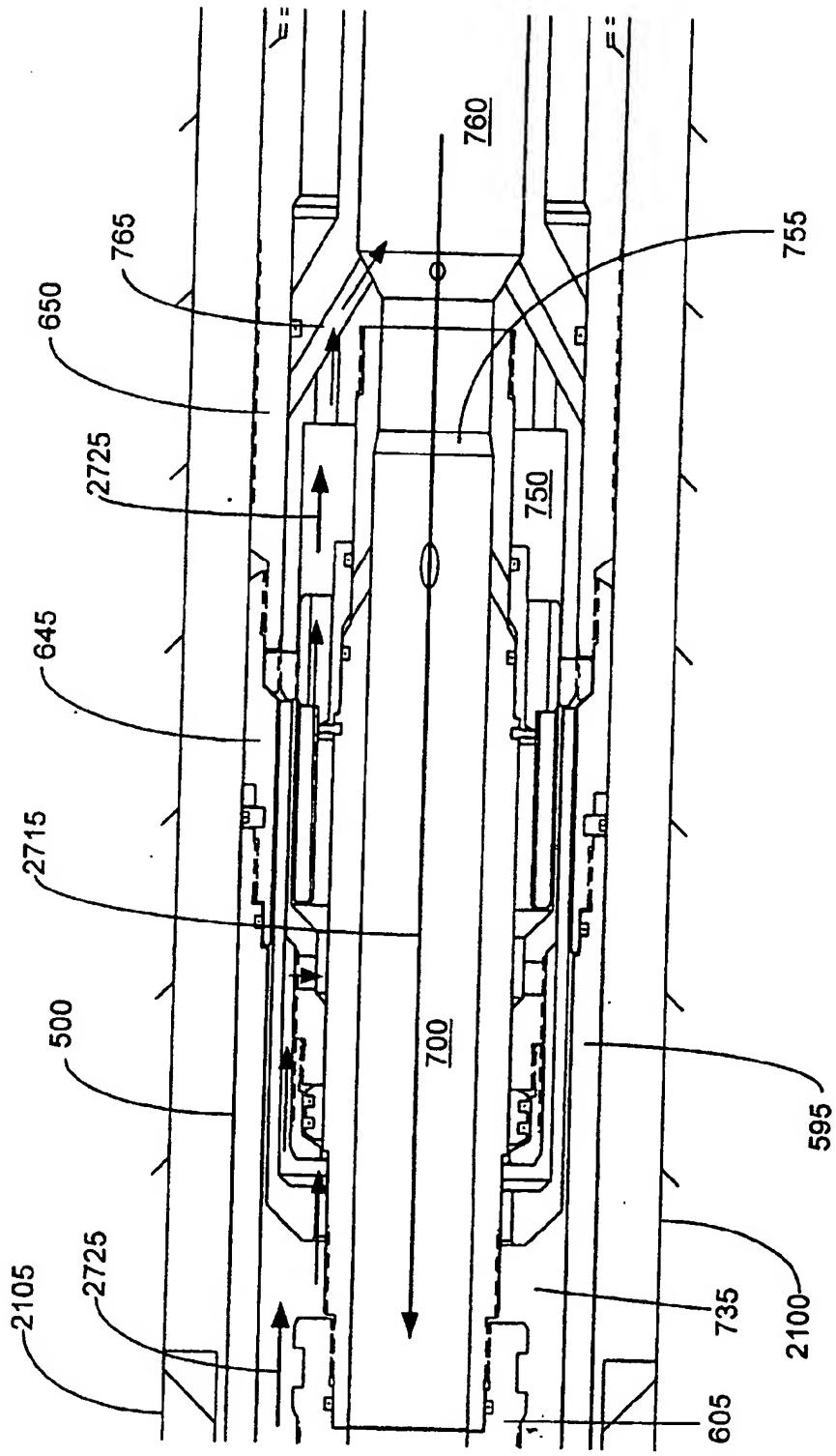


FIGURE 9G

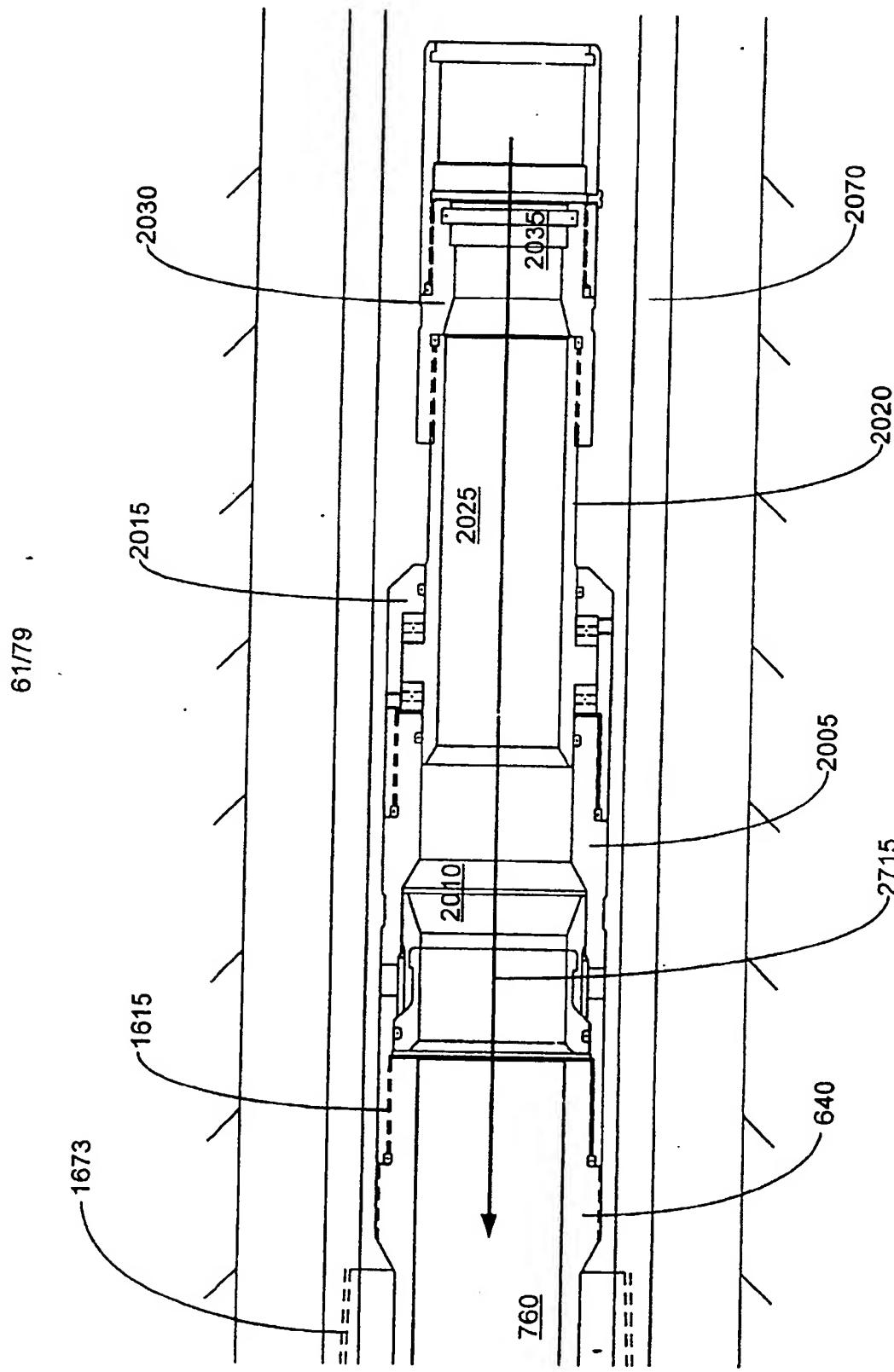


FIGURE 9H

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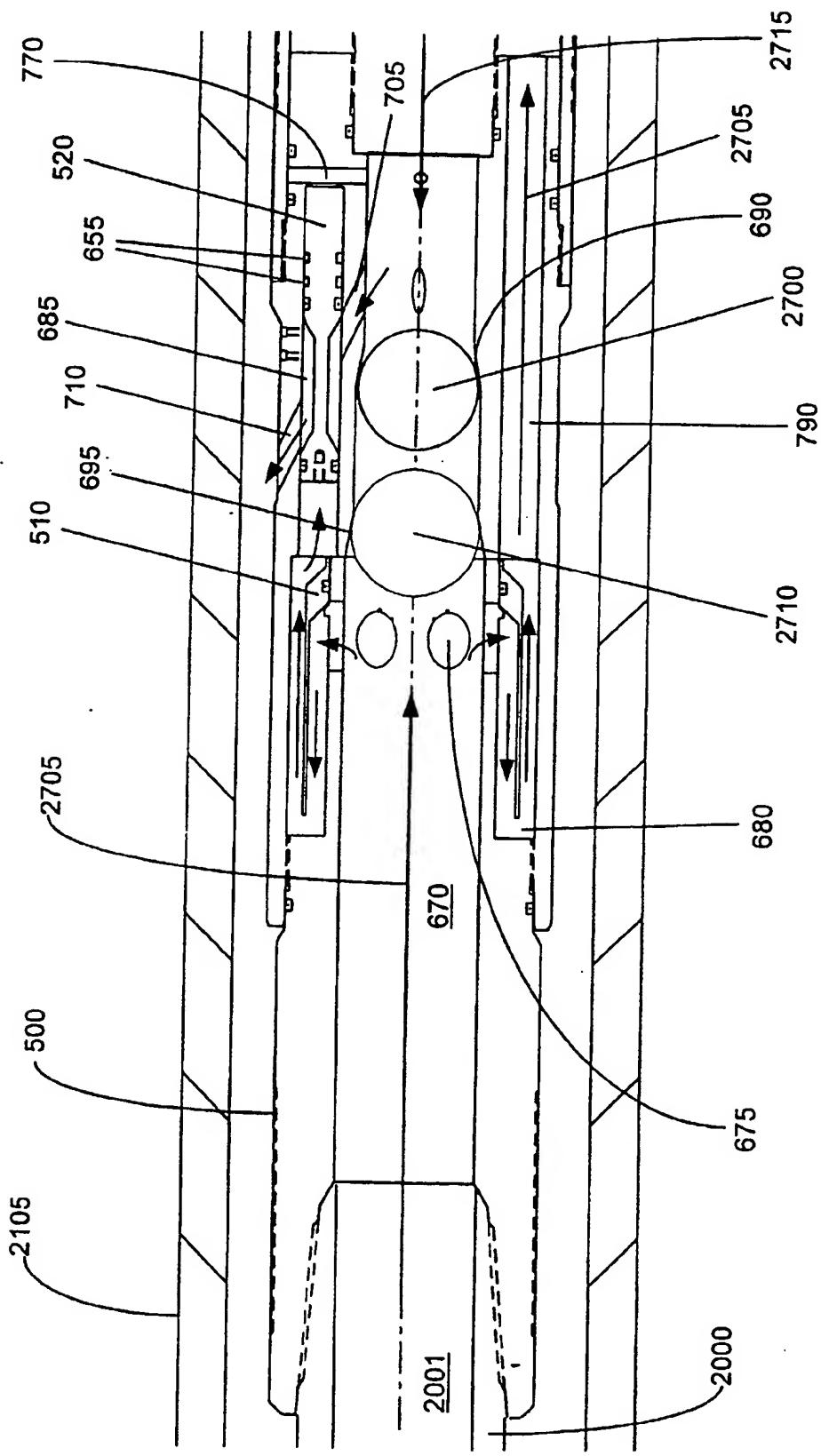


FIGURE 10A

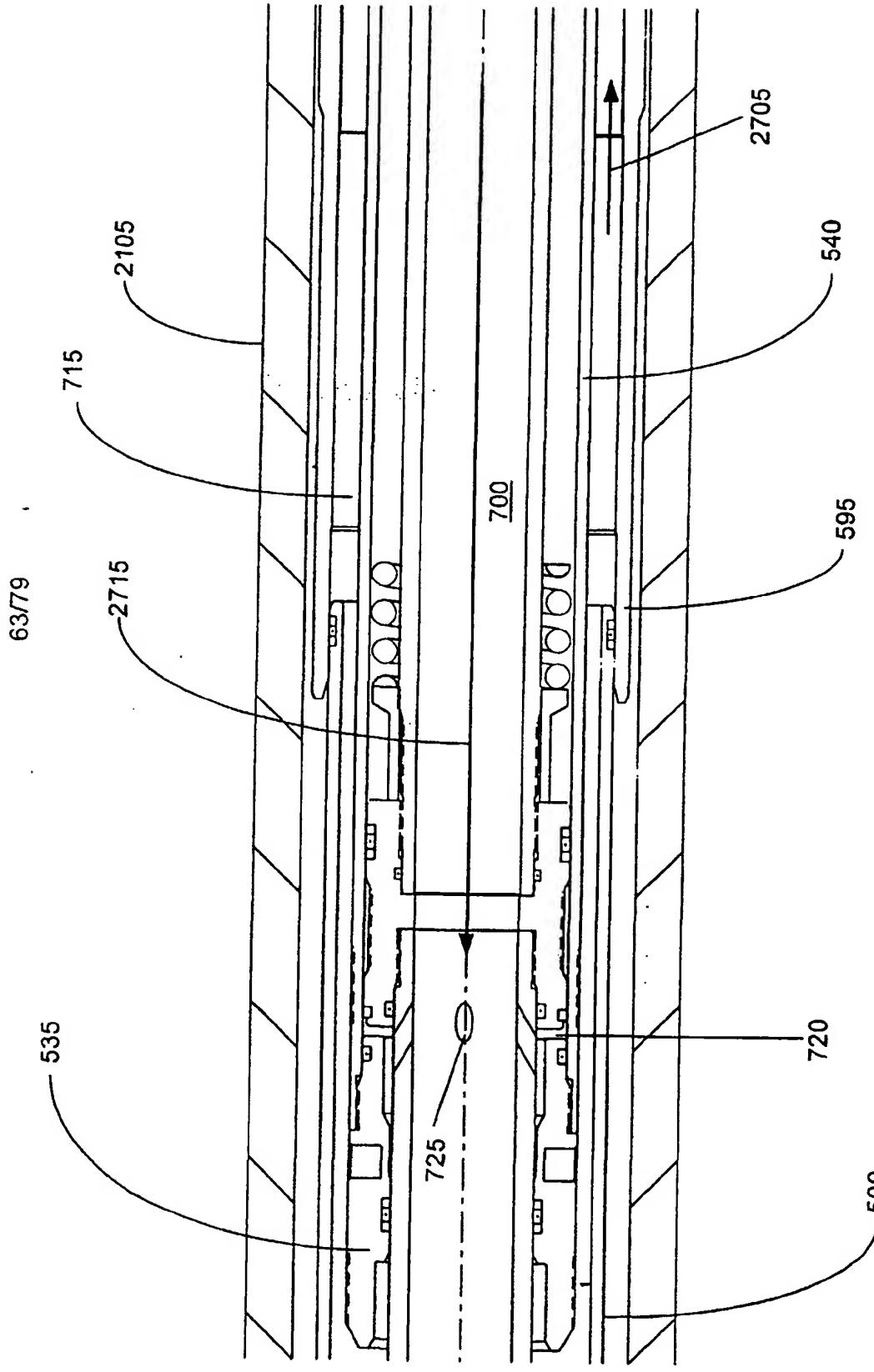
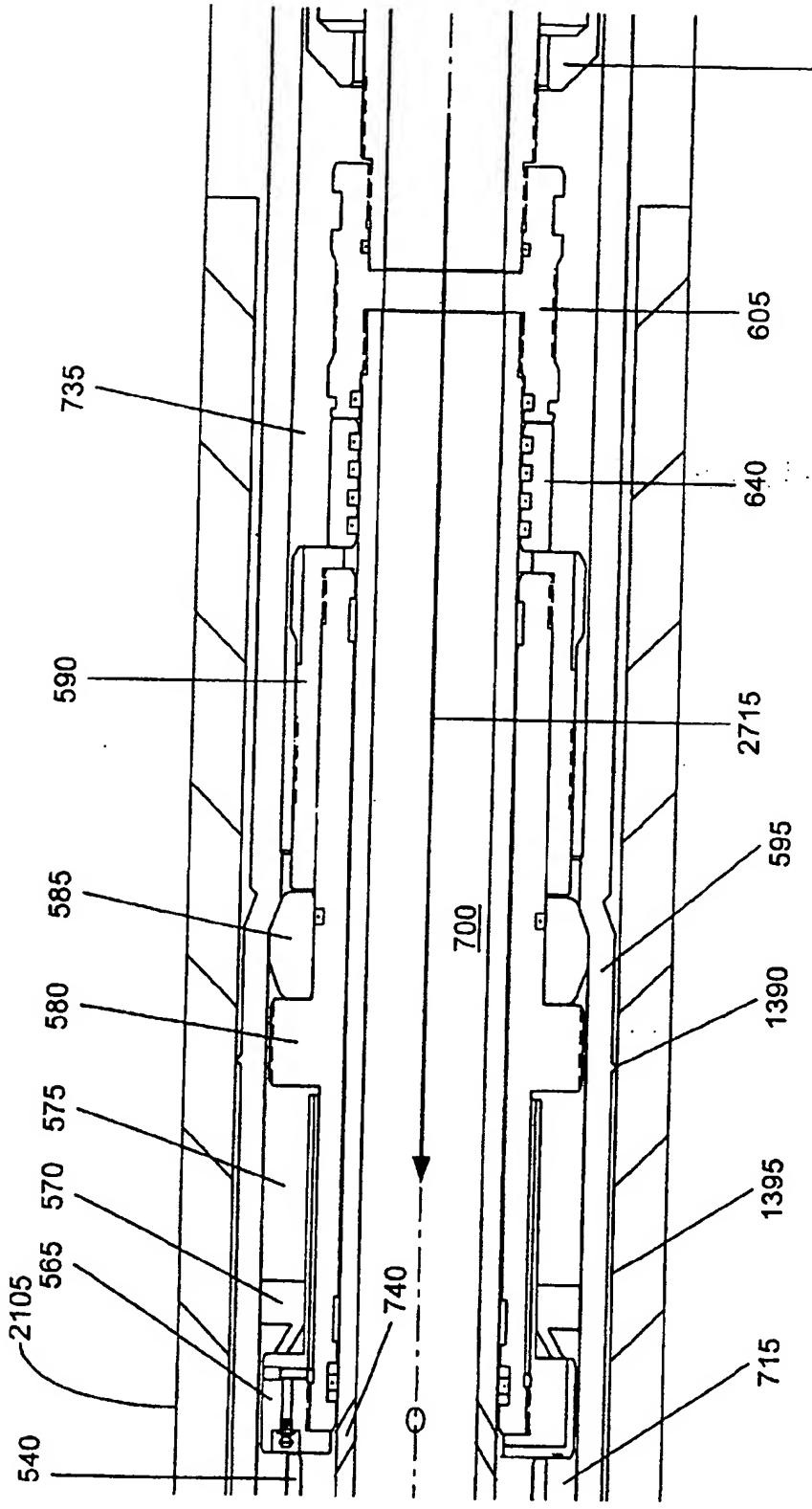


FIGURE 10B

FIGURE 10C

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ring with seal backups available from Parker Seals in order to optimally provide a fluidic seal. The second threaded portion 1250 of the second end 1220 of the first coupling 545 is preferably adapted to be removably coupled to the third support member 550. The second threaded portion 1250 may comprise any number of

5 conventional commercially available threaded portions. The second threaded portion 1250 is preferably a stub acme thread available from Halliburton Energy Services in order to optimally provide high tensile strength.

The third support member 550 is coupled to the first coupling 545 and the second coupling 605. The third support member 550 is movably coupled to the spring spacer 555, the preload spring 560, the mandrel 580, and the travel port sealing sleeve 600. The third support member 550 preferably has a substantially annular cross-section. The third support member 550 may be fabricated from any number of conventional commercially available materials. The third support member 550 is preferably fabricated from alloy steel having a minimum yield strength ranging from

10 about 75,000 to 140,000 psi in order to optimally provide high strength and resistance to abrasion and fluid erosion. The outer surface of the third support member 550 preferably includes a nickel plating in order to provide an optimal dynamic seal with the inside surfaces of the mandrel 580 and the travel port sealing sleeve 600. The third support member 550 preferably further includes a first end 1255, a second end 1260, a

15 first threaded portion 1265, and a second threaded portion 1270.

The first end 1255 of the third support member 550 preferably includes the first threaded portion 1265 and the fourth passage 700. The first threaded portion 1265 of the first end 1255 of the third support member 550 is preferably adapted to be removably coupled to the second threaded portion 1250 of the second end 1220 of the

20 first coupling 545. The first threaded portion 1265 may comprise any number of conventional commercially available threaded portions. The first threaded portion 1265 is preferably a stub acme thread available from Halliburton Energy Services in order to optimally provide high tensile strength.

The second end 1260 of the third support member 550 preferably includes the second threaded portion 1270 and the fourth passage 700, and the expansion cone travel indicator ports 740. The second threaded portion 1270 of the second end 1260 of the third support member 550 is preferably adapted to be removably coupled to the second coupling 605. The second threaded portion 1270 may comprise any number of conventional commercially available threaded portions. The second threaded portion 1270 is preferably a stub acme thread available from Halliburton Energy Services in order to optimally provide high tensile strength.

The spring spacer 555 is coupled to the preload spring 560. The spring spacer is movably coupled to the third support member 550. The spring spacer 555 preferably has a substantially annular cross-section. The spring spacer 555 may be fabricated from any number of conventional commercially available materials. The spring spacer 555 is preferably fabricated from alloy steel having a minimum yield strength ranging from about 75,000 to 140,000 psi in order to optimally provide high strength and resistance to abrasion and fluid erosion.

The preload spring 560 is coupled to the spring spacer 555. The preload spring 560 is movably coupled to the third support member 550. The preload spring 560 may be fabricated from any number of conventional commercially available materials. The preload spring 560 is preferably fabricated from alloys of chromium-vanadium or chromium-silicon in order to optimally provide a high preload force for sealing the interface between the expansion cone 585 and the liner hanger 595. The preload spring 560 preferably has a spring rate ranging from about 500 to 2000 lbf/in in order to optimally provide a preload force.

The lubrication fitting 565 is coupled to the lubrication packer sleeve 570, the body of lubricant 575 and the mandrel 580. The lubrication fitting 565 preferably has a substantially annular cross-section. The lubrication fitting 565 may be fabricated from any number of conventional commercially available materials. The lubrication fitting 565 is preferably fabricated from alloy steel having a minimum yield strength ranging

from about 75,000 to 140,000 psi in order to optimally provide high strength and resistance to abrasion and fluid erosion. The lubrication fitting 565 preferably includes a first end 1275, a second end 1280, a lubrication injection fitting 1285, a first threaded portion 1290, and the first lubrication supply passage 795.

- 5 The first end 1275 of the lubrication fitting 565 preferably includes the lubrication injection fitting 1285, the first threaded portion 1290 and the first lubrication supply passage 795. The lubrication injection fitting 1285 is preferably adapted to permit lubricants to be injected into the first lubrication supply passage 795. The lubrication injection fitting 1285 may comprise any number of conventional commercially available injection fittings. The lubrication injection fitting 1285 is preferably a model 1641-B grease fitting available from Alemite Corp. in order to optimally provide a connection for injecting lubricants. The first threaded portion 1290 of the first end 1275 of the lubrication fitting 565 is preferably adapted to be removably coupled to the mandrel 580. The first threaded portion 1290 may comprise any number of conventional commercially available threaded portions. The first threaded portion 1290 is preferably a stub acme thread available from Halliburton Energy Services. The second end 1280 of the lubrication fitting 565 is preferably spaced above the outside surface of the mandrel 580 in order to define a portion of the first lubrication supply passage 795.
- 10 The lubrication packer sleeve 570 is coupled to the lubrication fitting 565 and the body of lubricant 575. The lubrication packer sleeve 570 is movably coupled to the liner hanger 595. The lubrication packer sleeve 570 is preferably adapted to fluidically seal the radial gap between the outside surface of the second end 1280 of the lubrication fitting 565 and the inside surface of the liner hanger 595. The lubrication packer sleeve 570 is further preferably adapted to compress the body of lubricant 575. In this manner, the lubricants within the body of lubricant 575 are optimally pumped to outer surface of the expansion cone 585.
- 15
- 20
- 25

The lubrication packer sleeve 570 may comprise any number of conventional commercially available packer sleeves. The lubrication packer sleeve 570 is preferably a 70 durometer packer available from Halliburton Energy Services in order to optimally provide a low pressure fluidic seal.

- 5 The body of lubricant 575 is fluidically coupled to the first lubrication supply passage 795 and the second lubrication supply passage 800. The body of lubricant 575 is movably coupled to the lubrication fitting 565, the lubrication packer sleeve 570, the mandrel 580, the expansion cone 585 and the liner hanger 595. The body of lubricant 575 preferably provides a supply of lubricant for lubricating the dynamic interface between the outside surface of the expansion cone 585 and the inside surface of the liner hanger 595. The body of lubricant 575 may include any number of conventional commercially available lubricants. The body of lubricant 575 preferably includes anti-seize 1500 available from Climax Lubricants and Equipment Co. in order to optimally provide high pressure lubrication.
- 10 During operation of the apparatus 500, preferably the body of lubricant 575 lubricates the interface between the interior surface of the expanded portion of the liner hanger 595 and the exterior surface of the expansion cone 585. In this manner, when the expansion cone 585 is removed from the interior of the radially expanded liner hanger 595, the body of lubricant 575 lubricates the dynamic interfaces between the interior surface of the expanded portion of the liner hanger 595 and the exterior surface of the expansion cone 585. Thus, the body of lubricant 575 optimally reduces the force required to remove the expansion cone 585 from the radially expanded liner hanger 595.
- 15 The mandrel 580 is coupled to the lubrication fitting 565, the expansion cone 585, and the centralizer 590. The mandrel 580 is movably coupled to the third support member 550, the body of lubricant 575, and the liner hanger 595. The mandrel 580 preferably has a substantially annular cross-section. The mandrel 580 may be fabricated from any number of conventional commercially available materials. The

mandrel 580 is preferably fabricated from alloy steel having a minimum yield strength ranging from about 75,000 to 140,000 psi in order to optimally provide high strength and resistance to abrasion and fluid erosion. The mandrel 580 preferably further includes a first end 1295, an intermediate portion 1300, second end 1305, a first threaded portion 1310, a first sealing member 1315, a second sealing member 1320, and a second threaded portion 1325, a first wear ring 1326, and a second wear ring 1327.

The first end 1295 of the mandrel 580 preferably includes the first threaded portion 1310, the first sealing member 1315, and the first wear ring 1326. The first threaded portion 1310 is preferably adapted to be removably coupled to the first threaded portion 1290 of the first end 1275 of the lubrication fitting 565. The first threaded portion 1310 may comprise any number of conventional commercially available threaded portions. The first threaded portion 1310 is preferably a stub acme thread available from Halliburton Energy Services in order to optimally provide high tensile strength. The first sealing member 1315 is preferably adapted to fluidically seal the dynamic interface between the inside surface of the first end 1295 of the mandrel 580 and the outside surface of the third support member 550. The first sealing member 1315 may comprise any number of conventional commercially available sealing members. The first sealing member 1315 is preferably an o-ring with seal backups available from Parker Seals in order to optimally provide a dynamic fluidic seal. The first wear ring 1326 is preferably positioned within an interior groove formed in the first end 1295 of the mandrel 580. The first wear ring 1326 is preferably adapted to maintain concentricity between and among the mandrel 580 and the third support member 550 during axial displacement of the mandrel 580, reduce frictional forces, and support side loads. The first wear ring 1326 is preferably a model GR2C wear ring available from Busak & Shamban.

The outside diameter of the intermediate portion 1300 of the mandrel 580 is preferably about 0.05 to 0.25 inches less than the inside diameter of the line hanger

595. In this manner, the second lubrication supply passage 800 is defined by the radial gap between the intermediate portion 1300 of the mandrel 580 and the liner hanger 595.

- The second end 1305 of the mandrel 580 preferably includes the second sealing member 1320, the second threaded portion 1325, and the second wear ring 1327. The 5 second sealing member 1320 is preferably adapted to fluidically seal the interface between the inside surface of the expansion cone 585 and the outside surface of the mandrel 580. The second sealing member 1320 may comprise any number of conventional commercially available sealing members. The second sealing member 1320 is preferably an o-ring sealing member available from Parker Seals in order to optimally provide a fluidic seal. The second threaded portion 1325 is preferably 10 adapted to be removably coupled to the centralizer 590. The second threaded portion 1325 may comprise any number of conventional commercially available threaded portions. The second threaded portion 1325 is preferably a stub acme thread available from Halliburton Energy Services in order to optimally provide high tensile strength.
- 15 The second wear ring 1327 is preferably positioned within an interior groove formed in the second end 1305 of the mandrel 580. The second wear ring 1327 is preferably adapted to maintain concentricity between and among the mandrel 580 and the third support member 550 during axial displacement of the mandrel 580, reduce frictional forces, and support side loads. The second wear ring 1327 is preferably a model GR2C 20 wear ring available from Busak & Shamban.

The expansion cone 585 is coupled to the mandrel 580 and the centralizer 590. The expansion cone 585 is fluidically coupled to the second lubrication supply passage 800. The expansion cone 585 is movably coupled to the body of lubricant 575 and the liner hanger 595. The expansion cone 585 preferably includes a substantially annular 25 cross-section. The expansion cone 585 may be fabricated from any number of conventional commercially available materials. The expansion cone 585 is preferably fabricated from cold worked tool steel in order to optimally provide high strength and wear resistance.

- The expansion cone 585 is preferably further provided substantially as described in one or more of the following: (1) U.S. Patent Application Serial No. 09/440,338, attorney docket number 25791.9.02, filed on 11/15/1999 now United States Patent 6,328,113, which claimed benefit of the filing date of U.S. Provisional Patent
- 5 Application Serial Number 60/108,558, attorney docket number 25791.9, filed on 11/16/1998, (2) U.S. Patent Application Serial No. 09/454,139, attorney docket number 25791.3.02, filed on 12/31/1999 now United States Patent 6,497,289, which claimed benefit of the filing date of U.S. Provisional Patent Application Serial Number 60/111,293, filed on 12/7/1998, (3) U.S. Patent Application Serial Number 09/502,350,
- 10 attorney docket number 25791.8.02, filed on 2/10/2000, which claimed the benefit of the filing date of U.S. Provisional Patent Application Serial Number 60/119,611, attorney docket number 25791.8, filed 2/11/1999, (4) U.S. Patent Application Serial Number 09/510,913, attorney docket number 25791.7.02, filed on 2/23/2000, which claimed the benefit of the filing date of U.S. Provisional Patent Application Serial
- 15 Number 60/121,702, attorney docket number 25791.7, filed on 2/25/1999, (5) U.S. Patent Application Serial Number 09/511,941, attorney docket number 25791.16.02, filed on 2/24/2000 now United States Patent 6,575,240, which claimed the benefit of the filing date of U.S. Provisional Patent Application number 60/121,907, attorney docket number 25791.16, filed 2/26/1999, (6) U.S. Provisional Patent Application
- 20 Serial Number 60/124,042, attorney docket number 25791.11, filed on 3/11/1999, (7) U.S. Provisional Patent Application Serial Number 60/131,106, attorney docket number 25791.23, filed on 4/26/1999, (8) U.S. Provisional Patent Application Serial Number 60/137,998, attorney docket number 25791.17, filed on 6/7/1999, (9) U.S. Provisional Patent Application Serial Number 60/143,039, attorney docket number 25791.26, filed
- 25 on 7/9/1999, and (10) U.S. Provisional Patent Application Serial Number 60/146,203, attorney docket number 25791.25, filed on 7/29/1999, the disclosures of which are incorporated by reference.

- The centralizer 590 is coupled to the mandrel 580 and the expansion cone 585. The centralizer 590 is movably coupled to the liner hanger 595. The centralizer 590 preferably includes a substantially annular cross-section. The centralizer 590 may be fabricated from any number of conventional commercially available materials. The
- 5 centralizer 590 is preferably fabricated from alloy steel having a minimum yield strength ranging from about 75,000 to 140,000 in order to optimally provide high strength and resistance to abrasion and fluid erosion. The centralizer 590 preferably includes a first end 1330, a second end 1335, a plurality of centralizer fins 1340, and a threaded portion 1345.
- 10 The second end 1335 of the centralizer 590 preferably includes the centralizer fins 1340 and the threaded portion 1345. The centralizer fins 1340 preferably extend from the second end 1335 of the centralizer 590 in a substantially radial direction. The radial gap between the centralizer fins 1340 and the inside surface of the liner hanger 595 is preferably less than about 0.06 inches in order to optimally provide
- 15 centralization of the expansion cone 585. The threaded portion 1345 is preferably adapted to be removably coupled to the second threaded portion 1325 of the second end 1305 of the mandrel 580. The threaded portion 1345 may comprise any number of conventional commercially available threaded portions. The threaded portion 1345 is preferably a stub acme thread in order to optimally provide high tensile strength.
- 20 The liner hanger 595 is coupled to the outer collet support member 645 and the set screws 660. The liner hanger 595 is movably coupled to the lubrication packer sleeve 570, the body of lubricant 575, the expansion cone 585, and the centralizer 590. The liner hanger 595 preferably has a substantially annular cross-section. The liner hanger 595 preferably includes a plurality of tubular members coupled end to end. The
- 25 axial length of the liner hanger 595 preferably ranges from about 5 to 12 feet. The liner hanger 595 may be fabricated from any number of conventional commercially available materials. The liner hanger 595 is preferably fabricated from alloy steel having a minimum yield strength ranging from about 40,000 to 125,000 psi in order to optimally

provide high strength and ductility. The liner hanger 595 preferably includes a first end 1350, an intermediate portion 1355, a second end 1360, a sealing member 1365, a threaded portion 1370, one or more set screw mounting holes 1375, and one or more outside sealing portions 1380.

- 5 The outside diameter of the first end 1350 of the liner hanger 595 is preferably selected to permit the liner hanger 595 and apparatus 500 to be inserted into another opening or tubular member. The outside diameter of the first end 1350 of the liner hanger 595 is preferably selected to be about 0.12 to 2 inches less than the inside diameter of the opening or tubular member that the liner hanger 595 will be inserted
10 into. The axial length of the first end 1350 of the liner hanger 595 preferably ranges from about 8 to 20 inches.

The outside diameter of the intermediate portion 1355 of the liner hanger 595 preferably provides a transition from the first end 1350 to the second end 1360 of the liner hanger. The axial length of the intermediate portion 1355 of the liner hanger 595
15 preferably ranges from about 0.25 to 2 inches in order to optimally provide reduced radial expansion pressures.

- The second end 1360 of the liner hanger 595 includes the sealing member 1365, the threaded portion 1370, the set screw mounting holes 1375 and the outside sealing portions 1380. The outside diameter of the second end 1360 of the liner hanger 595 is
20 preferably about 0.10 to 2.00 inches less than the outside diameter of the first end 1350 of the liner hanger 595 in order to optimally provide reduced radial expansion pressures. The sealing member 1365 is preferably adapted to fluidically seal the interface between the second end 1360 of the liner hanger and the outer collet support member 645. The sealing member 1365 may comprise any number of conventional
25 commercially available sealing members. The sealing member 1365 is preferably an o-ring seal available from Parker Seals in order to optimally provide a fluidic seal. The threaded portion 1370 is preferably adapted to be removably coupled to the outer collet support member 645. The threaded portion 1370 may comprise any number of

conventional commercially available threaded portions. The threaded portion 1370 is preferably a stub acme thread available from Halliburton Energy Services in order to optimally provide high tensile strength. The set screw mounting holes 1375 are preferably adapted to receive the set screws 660. Each outside sealing portion 1380

5 preferably includes a top ring 1385, an intermediate sealing member 1395, and a lower ring 1390. The top and bottom rings, 1385 and 1390, are preferably adapted to penetrate the inside surface of a wellbore casing. The top and bottom rings, 1385 and 1390, preferably extend from the outside surface of the second end 1360 of the liner hanger 595. The outside diameter of the top and bottom rings, 1385 and 1390,

10 preferably are less than or equal to the outside diameter of the first end 1350 of the liner hanger 595 in order to optimally provide protection from abrasion when placing the apparatus 500 within a wellbore casing or other tubular member. The top and bottom rings, 1385 and 1390 are preferably fabricated from alloy steel having a minimum yield strength of about 40,000 to 125,000 psi in order to optimally provide high strength and

15 ductility. The top and bottom rings, 1385 and 1390, are preferably integrally formed with the liner hanger 595. The intermediate sealing member 1395 is preferably adapted to seal the interface between the outside surface of the second end 1360 of the liner hanger 595 and the inside surface of a wellbore casing. The intermediate sealing member 1395 may comprise any number of conventional sealing members. The

20 intermediate sealing member 1395 is preferably a 50 to 90 durometer nitrile elastomeric sealing member available from Eutsler Technical Products in order to optimally provide a fluidic seal and shear strength.

The liner hanger 595 is further preferably provided substantially as described in one or more of the following: (1) U.S. Patent Application Serial No. 09/440,338, attorney docket number 25791.9.02, filed on 11/15/1999 now United States Patent 6,328,113, which claimed benefit of the filing date of U.S. Provisional Patent Application Serial Number 60/108,558, attorney docket number 25791.9, filed on 11/16/1998, (2) U.S. Patent Application Serial No. 09/454,139, attorney docket number

25791.3.02, filed on 12/31/1999 now United States Patent 6,497,289, which claimed benefit of the filing date of U.S. Provisional Patent Application Serial Number 60/111,293, filed on 12/7/1998, (3) U.S. Patent Application Serial Number 09/502,350, attorney docket number 25791.8.02, filed on 2/10/2000, which claimed the benefit of
5 the filing date of U.S. Provisional Patent Application Serial Number 60/119,611, attorney docket number 25791.8, filed 2/11/1999, (4) U.S. Patent Application Serial Number 09/510,913, attorney docket number 25791.7.02, filed on 2/23/2000, which claimed the benefit of the filing date of U.S. Provisional Patent Application Serial Number 60/121,702, attorney docket number 25791.7, filed on 2/25/1999, (5) U.S.
10 Patent Application Serial Number 09/511,941, attorney docket number 25791.16.02, filed on 2/24/2000 now United States Patent 6,575,240, which claimed the benefit of the filing date of U.S. Provisional Patent Application number 60/121,907, attorney docket number 25791.16, filed 2/26/1999, (6) U.S. Provisional Patent Application Serial Number 60/124,042, attorney docket number 25791.11, filed on 3/11/1999, (7)
15 U.S. Provisional Patent Application Serial Number 60/131,106, attorney docket number 25791.23, filed on 4/26/1999, (8) U.S. Provisional Patent Application Serial Number 60/137,998, attorney docket number 25791.17, filed on 6/7/1999, (9) U.S. Provisional Patent Application Serial Number 60/143,039, attorney docket number 25791.26, filed on 7/9/1999, and (10) U.S. Provisional Patent Application Serial Number 60/146,203,
20 attorney docket number 25791.25, filed on 7/29/1999, the disclosures of which are incorporated by reference.

The travel port sealing sleeve 600 is movably coupled to the third support member 550. The travel port sealing sleeve 600 is further initially positioned over the expansion cone travel indicator ports 740. The travel port sealing sleeve 600 preferably
25 has a substantially annular cross-section. The travel port sealing sleeve 600 may be fabricated from any number of conventional commercially available materials. The travel port sealing sleeve 600 is preferably fabricated from alloy steel having a minimum yield strength of about 75,000 to 140,000 psi in order to optimally provide

- high strength and resistance to abrasion and fluid erosion. The travel port sealing sleeve preferably includes a plurality of inner sealing members 1400. The inner sealing members 1400 are preferably adapted to seal the dynamic interface between the inside surface of the travel port sealing sleeve 600 and the outside surface of the third support member 550. The inner sealing members 1400 may comprise any number of conventional commercially available sealing members. The inner sealing members 1400 are preferably o-rings available from Parker Seals in order to optimally provide a fluidic seal. The inner sealing members 1400 preferably further provide sufficient frictional force to prevent inadvertent movement of the travel port sealing sleeve 600.
- 5 The travel port sealing sleeve 600 is preferably removably coupled to the third support member 550 by one or more shear pins. In this manner, accidental movement of the travel port sealing sleeve 600 is prevented.
- 10 The travel port sealing sleeve 600 is preferably removably coupled to the third support member 550 by one or more shear pins. In this manner, accidental movement of the travel port sealing sleeve 600 is prevented.

The second coupling 605 is coupled to the third support member 550 and the collet mandrel 610. The second coupling 605 preferably has a substantially annular cross-section. The second coupling 605 may be fabricated from any number of conventional commercially available materials. The second coupling 605 is preferably fabricated from alloy steel having a minimum yield strength of about 75,000 to 140,000 psi in order to optimally provide high strength and resistance to abrasion and fluid erosion. The second coupling 605 preferably further includes the fourth passage 700, a first end 1405, a second end 1410, a first inner sealing member 1415, a first threaded portion 1420, a second inner sealing member 1425, and a second threaded portion 1430.

The first end 1405 of the second coupling 605 preferably includes the first inner sealing member 1415 and the first threaded portion 1420. The first inner sealing member 1415 is preferably adapted to fluidically seal the interface between the first end 1405 of the second coupling 605 and the second end 1260 of the third support member 550. The first inner sealing member 1415 may include any number of conventional commercially available sealing members. The first inner sealing member 1415 is

preferably an o-ring available from Parker Seals in order to optimally provide a fluidic seal. The first threaded portion 1420 of the first end 1415 of the second coupling 605 is preferably adapted to be removably coupled to the second threaded portion 1270 of the second end 1260 of the third support member 550. The first threaded portion 1420 may 5 comprise any number of conventional commercially available threaded portions. The first threaded portion 1420 is preferably a stub acme thread available from Halliburton Energy Services in order to optimally provide high tensile strength.

The second end 1410 of the second coupling 605 preferably includes the second inner sealing member 1425 and the second threaded portion 1430. The second inner 10 sealing member 1425 is preferably adapted to fluidically seal the interface between the second end 1410 of the second coupling 605 and the collet mandrel 610. The second inner sealing member 1425 may include any number of conventional commercially available sealing members. The second inner sealing member 1425 is preferably an o-ring available from Parker Seals in order to optimally provide a fluidic seal. The 15 second threaded portion 1430 of the second end 1410 of the second coupling 605 is preferably adapted to be removably coupled to the collet mandrel 610. The second threaded portion 1430 may comprise any number of conventional commercially available threaded portions. The second threaded portion 1430 is preferably a stub acme thread available from Halliburton Energy Services in order to optimally provide 20 high tensile strength.

The collet mandrel 610 is coupled to the second coupling 605, the collet retaining adapter 640, and the collet retaining sleeve shear pins 665. The collet mandrel 610 is releasably coupled to the locking dogs 620, the collet assembly 625, and the collet retaining sleeve 635. The collet mandrel 610 preferably has a substantially 25 annular cross-section. The collet mandrel 610 may be fabricated from any number of conventional commercially available materials. The collet mandrel 610 is preferably fabricated from alloy steel having a minimum yield strength of about 75,000 to 140,000 psi in order to optimally provide high strength and resistance to abrasion and fluid

erosion. The collet mandrel 610 preferably further includes the fourth passage 700, the collet release ports 745, the collet release throat passage 755, the fifth passage 760, a first end 1435, a second end 1440, a first shoulder 1445, a second shoulder 1450, a recess 1455, a shear pin mounting hole 1460, a first threaded portion 1465, a second threaded portion 1470, and a sealing member 1475.

5 The first end 1435 of the collet mandrel 610 preferably includes the fourth passage 700, the first shoulder 1445, and the first threaded portion 1465. The first threaded portion 1465 is preferably adapted to be removably coupled to the second threaded portion 1430 of the second end 1410 of the second coupling 605. The first 10 threaded portion 1465 may include any number of conventional threaded portions. The first threaded portion 1465 is preferably a stub acme thread available from Halliburton Energy Services in order to optimally provide high tensile strength.

10 The second end 1440 of the collet mandrel 610 preferably includes the fourth passage 700, the collet release ports 745, the collet release throat passage 755, the fifth passage 760, the second shoulder 1450, the recess 1455, the shear pin mounting hole 1460, the second threaded portion 1470, and the sealing member 1475. The second shoulder 1450 is preferably adapted to mate with and provide a reference position for 15 the collet retaining sleeve 635. The recess 1455 is preferably adapted to define a portion of the collet sleeve release chamber 805. The shear pin mounting hole 1460 is preferably adapted to receive the collet retaining sleeve shear pins 665. The second threaded portion 1470 is preferably adapted to be removably coupled to the collet retaining adapter 640. The second threaded portion 1470 may include any number of conventional commercially available threaded portions. The second threaded portions 20 1470 is preferably a stub acme thread available from Halliburton Energy Services in order to optimally provide high tensile strength. The sealing member 1475 is preferably adapted to seal the dynamic interface between the outside surface of the collet mandrel 610 and the inside surface of the collet retaining sleeve 635. The sealing member 1475 may include any number of conventional commercially available sealing 25

members. The sealing member 1475 is preferably an o-ring available from Parker Seals in order to optimally provide a fluidic seal.

The load transfer sleeve 615 is movably coupled to the collet mandrel 610, the collet assembly 625, and the outer collet support member 645. The load transfer sleeve 5 615 preferably has a substantially annular cross-section. The load transfer sleeve 615 may be fabricated from any number of conventional commercially available materials. The load transfer sleeve 615 is preferably fabricated from alloy steel having a minimum yield strength of about 75,000 to 140,000 psi in order to optimally provide high strength and resistance to abrasion and fluid erosion. The load transfer sleeve 615 10 preferably further a first end 1480 and a second end 1485.

The inside diameter of the first end 1480 of the load transfer sleeve 615 is preferably greater than the outside diameter of the collet mandrel 610 and less than the outside diameters of the second coupling 605 and the locking dog retainer 622. In this manner, during operation of the apparatus 500, the load transfer sleeve 615 optimally 15 permits the flow of fluidic materials from the second annular chamber 735 to the third annular chamber 750. Furthermore, in this manner, during operation of the apparatus 200, the load transfer sleeve 615 optimally limits downward movement of the second coupling 605 relative to the collet assembly 625.

The second end 1485 of the load transfer sleeve 615 is preferably adapted to 20 cooperatively interact with the collet 625. In this manner, during operation of the apparatus 200, the load transfer sleeve 615 optimally limits downward movement of the second coupling 605 relative to the collet assembly 625.

The locking dogs 620 are coupled to the locking dog retainer 622 and the collet assembly 625. The locking dogs 620 are releasably coupled to the collet mandrel 610. 25 The locking dogs 620 are preferably adapted to lock onto the outside surface of the collet mandrel 610 when the collet mandrel 610 is displaced in the downward direction relative to the locking dogs 620. The locking dogs 620 may comprise any number of conventional commercially available locking dogs. The locking dogs 620 preferably

include a plurality of locking dog elements 1490 and a plurality of locking dog springs 1495.

Each of the locking dog elements 1490 preferably include an arcuate segment including a pair of external grooves for receiving the locking dog springs 1495. Each 5 of the locking dog springs 1495 are preferably garter springs. During operation of the apparatus 500, the locking dog elements 1490 are preferably radially inwardly displaced by the locking dog springs 1495 when the locking dogs 620 are relatively axially displaced past the first shoulder 1445 of the collet mandrel 610. As a result, the locking dogs 620 are then engaged by the first shoulder 1445 of the collet mandrel 610.

10 The locking dog retainer 622 is coupled to the locking dogs 620 and the collet assembly 625. The locking dog retainer 622 preferably has a substantially annular cross-section. The locking dog retainer 622 may be fabricated from any number of conventional commercially available materials. The locking dog retainer 622 is preferably fabricated from alloy steel having a minimum yield strength of about 75,000 15 to 140,000 psi in order to optimally provide high strength and resistance to abrasion and fluid erosion. The locking dog retainer 622 preferably further includes a first end 1500, a second end 1505, and a threaded portion 1510.

The first end 1500 of the locking dog retainer 622 is preferably adapted to capture the locking dogs 620. In this manner, when the locking dogs 620 latch onto the 20 first shoulder 1445 of the collet mandrel 610, the locking dog retainer 622 transmits the axial force to the collet assembly 625.

The second end 1505 of the locking dog retainer preferably includes the threaded portion 1510. The threaded portion 1510 is preferably adapted to be removably coupled to the collet assembly 625. The threaded portion 1510 may 25 comprise any number of conventional commercially available threaded portions. The threaded portions 1510 is preferably a stub acme thread available from Halliburton Energy Services in order to optimally provide high tensile strength.

The collet assembly 625 is coupled to the locking dogs 620 and the locking dog retainer 622. The collet assembly 625 is releasably coupled to the collet mandrel 610, the outer collet support member 645, the collet retaining sleeve 635, the load transfer sleeve 615, and the collet retaining adapter 640.

- 5 The collet assembly 625 preferably has a substantially annular cross-section. The collet assembly 625 may be fabricated from any number of conventional commercially available materials. The collet assembly 625 is preferably fabricated from alloy steel having a minimum yield strength of about 75,000 to 140,000 psi in order to optimally provide high strength and resistance to abrasion and fluid erosion. The collet assembly 10 625 preferably includes a collet body 1515, a plurality of collet arms 1520, a plurality of collet upsets 1525, flow passages 1530, and a threaded portion 1535.

The collet body 1515 preferably includes the flow passages 1530 and the threaded portion 1535. The flow passages 1530 are preferably adapted to convey fluidic materials between the second annular chamber 735 and the third annular chamber 750. The threaded portion 1535 is preferably adapted to be removably coupled to the threaded portion 1510 of the second end 1505 of the locking dog retainer 622. The threaded portion 1535 may include any number of conventional commercially available threaded portions. The threaded portion 1535 is preferably a stub acme thread available from Halliburton Energy Services in order to optimally 15 20 provide high tensile strength.

The collet arms 1520 extend from the collet body 1515 in a substantially axial direction. The collet upsets 1525 extend from the ends of corresponding collet arms 1520 in a substantially radial direction. The collet upsets 1525 are preferably adapted to mate with and cooperatively interact with corresponding slots provided in the collet retaining adapter 640 and the liner hanger setting sleeve 650. In this manner, the collet 25 upsets 1525 preferably controllably couple the collet retaining adapter 640 to the outer collet support member 645 and the liner hanger setting sleeve 650. In this manner, axial and radial forces are optimally coupled between the collet retaining adapter 640,

the outer collet support member 645 and the liner hanger setting sleeve 650. The collet upsets 1525 preferably include a flat outer surface 1540 and an angled outer surface 1545. In this manner, the collet upsets 1525 are optimally adapted to be removably coupled to the slots provided in the collet retaining adapter 640 and the liner hanger setting sleeve 650.

5 The collet retaining sleeve 635 is coupled to the collet retaining sleeve shear pins 665. The collet retaining sleeve 635 is movably coupled to the collet mandrel 610 and the collet assembly 625. The collet retaining sleeve 635 preferably has a substantially annular cross-section. The collet retaining sleeve 635 may be fabricated 10 from any number of conventional commercially available materials. The collet retaining sleeve 635 is preferably fabricated from alloy steel having a minimum yield strength of about 75,000 to 140,000 psi in order to optimally provide high strength and resistance to abrasion and fluid erosion. The collet retaining sleeve 635 preferably includes the collet sleeve passages 775, a first end 1550, a second end 1555, one or 15 more shear pin mounting holes 1560, a first shoulder 1570, a second shoulder 1575, and a sealing member 1580.

10 The first end 1550 of the collet retaining sleeve 635 preferably includes the collet sleeve passages 775, the shear pin mounting holes 1560, and the first shoulder 1570. The collet sleeve passages 775 are preferably adapted to convey fluidic materials 20 between the second annular chamber 735 and the third annular chamber 750. The shear pin mounting holes 1560 are preferable adapted to receive corresponding shear pins 665. The first shoulder 1570 is preferably adapted to mate with the second shoulder 1450 of the collet mandrel 610.

15 The second end 1555 of the collet retaining sleeve 635 preferably includes the collet sleeve passages 775, the second shoulder 1575, and the sealing member 1580. The collet sleeve passages 775 are preferably adapted to convey fluidic materials 25 between the second annular chamber 735 and the third annular chamber 750. The second shoulder 1575 of the second end 1555 of the collet retaining sleeve 635 and the

recess 1455 of the second end 1440 of the collet mandrel 610 are preferably adapted to define the collet sleeve release chamber 805. The sealing member 1580 is preferably adapted to seal the dynamic interface between the outer surface of the collet mandrel 610 and the inside surface of the collet retaining sleeve 635. The sealing member 1580
5 may include any number of conventional commercially available sealing members. The sealing member 1580 is preferably an o-ring available from Parker Seals in order to optimally provide a fluidic seal.

The collet retaining adapter 640 is coupled to the collet mandrel 610. The collet retaining adapter 640 is movably coupled to the liner hanger setting sleeve 650, the
10 collet retaining sleeve 635, and the collet assembly 625. The collet retaining adapter 640 preferably has a substantially annular cross-section. The collet retaining adapter 640 may be fabricated from any number of conventional commercially available materials. The collet retaining adapter 640 is preferably fabricated from alloy steel having a minimum yield strength of about 75,000 to 140,000 psi in order to optimally
15 provide high strength and resistance to abrasion and fluid erosion. The collet retaining adapter 640 preferably includes the fifth passage 760, the sixth passages 765, a first end 1585, an intermediate portion 1590, a second end 1595, a plurality of collet slots 1600, a sealing member 1605, a first threaded portion 1610, and a second threaded portion 1615.

20 The first end 1585 of the collet retaining adapter 640 preferably includes the collet slots 1600. The collet slots 1600 are preferably adapted to cooperatively interact with and mate with the collet upsets 1525. The collet slots 1600 are further preferably adapted to be substantially aligned with corresponding collet slots provided in the liner hanger setting sleeve 650. In this manner, the slots provided in the collet retaining
25 adapter 640 and the liner hanger setting sleeve 650 are removably coupled to the collet upsets 1525.

The intermediate portion 1590 of the collet retaining adapter 640 preferably includes the sixth passages 765, the sealing member 1605, and the first threaded portion

1610. The sealing member 1605 is preferably adapted to fluidically seal the interface between the outside surface of the collet retaining adapter 640 and the inside surface of the liner hanger setting sleeve 650. The sealing member 1605 may include any number of conventional commercially available sealing members. The sealing member 1605 is
5 preferably an o-ring available from Parker Seals in order to optimally provide a fluidic seal. The first threaded portion 1610 is preferably adapted to be removably coupled to the second threaded portion 1470 of the second end 1440 of the collet mandrel 610. The first threaded portion 1610 may include any number of conventional commercially available threaded portions. The first threaded portion 1610 is preferably a stub acme
10 thread available from Halliburton Energy Services in order to optimally provide high tensile strength.

The second end 1595 of the collet retaining adapter 640 preferably includes the fifth passage 760 and the second threaded portion 1615. The second threaded portion 1615 is preferably adapted to be removably coupled to a conventional SSR plug set, or
15 other similar device.

The outer collet support member 645 is coupled to the liner hanger 595, the set screws 660, and the liner hanger setting sleeve 650. The outer collet support member 645 is releasably coupled to the collet assembly 625. The outer collet support member 645 is movably coupled to the load transfer sleeve 615. The outer collet support
20 member 645 preferably has a substantially annular cross-section. The outer collet support member 645 may be fabricated from any number of conventional commercially available materials. The outer collet support member 645 is preferably fabricated from alloy steel having a minimum yield strength of about 75,000 to 140,000 psi in order to optimally provide high strength and resistance to abrasion and fluid erosion. The outer collet support member 645 preferably includes a first end 1620, a second end 1625, a
25 first threaded portion 1630, set screw mounting holes 1635, a recess 1640, and a second threaded portion 1645.

- The first end 1620 of the outer collet support member 645 preferably includes the first threaded portion 1630 and the set screw mounting holes 1635. The first threaded portion 1630 is preferably adapted to be removably coupled to the threaded portion 1370 of the second end 1360 of the liner hanger 595. The first threaded portion
- 5 1630 may include any number of conventional commercially available threaded portions. The first threaded portion 1630 is preferably a stub acme thread available from Halliburton Energy Services in order to optimally provide high tensile strength. The set screw mounting holes 1635 are preferably adapted to receive corresponding set screws 660.
- 10 The second end 1625 of the outer collet support member 645 preferably includes the recess 1640 and the second threaded portion 1645. The recess 1640 is preferably adapted to receive a portion of the end of the liner hanger setting sleeve 650. In this manner, the second end 1625 of the outer collet support member 645 overlaps with a portion of the end of the liner hanger setting sleeve 650. The second threaded portion
- 15 1645 is preferably adapted to be removably coupled to the liner hanger setting sleeve 650. The second threaded portion 1645 may include any number of conventional commercially available threaded portions. The second threaded portion 1645 is preferably a stub acme thread available from Halliburton Energy Services in order to optimally provide high tensile strength.
- 20 The liner hanger setting sleeve 650 is coupled to the outer collet support member 645. The liner hanger setting sleeve 650 is releasably coupled to the collet assembly 625. The liner hanger setting sleeve 650 is movably coupled to the collet retaining adapter 640. The liner hanger setting sleeve 650 preferably has a substantially annular cross-section. The liner hanger setting sleeve 650 may be fabricated from any
- 25 number of conventional commercially available materials. The liner hanger setting sleeve 650 is preferably fabricated from alloy steel having a minimum yield strength of about 75,000 to 140,000 psi in order to optimally provide high strength and resistance to abrasion and fluid erosion. The liner hanger setting sleeve 650 preferably includes a

first end 1650, a second end 1655, a recessed portion 1660, a plurality of collet slots 1665, a threaded portion 1670, an interior shoulder 1672, and a threaded portion 1673.

The first end 1650 of the liner hanger setting sleeve 650 preferably includes the recessed portion 1660, the plurality of collet slots 1665 and the threaded portion 1670.

- 5 The recessed portion 1660 of the first end 1650 of the liner hanger setting sleeve 650 is preferably adapted to mate with the recessed portion 1640 of the second end 1625 of the outer collet support member 645. In this manner, the first end 1650 of the liner hanger setting sleeve 650 overlaps and mates with the second end 1625 of the outer collet support member 645. The recessed portion 1660 of the first end 1650 of the liner hanger setting sleeve 650 further includes the plurality of collet slots 1665. The collet slots 1665 are preferably adapted to mate with and cooperatively interact with the collet upsets 1525. The collet slots 1665 are further preferably adapted to be aligned with the collet slots 1600 of the collet retaining adapted 640. In this manner, the collet retaining adapter 640 and the liner hanger setting sleeve 650 preferably cooperatively interact
- 10 with and mate with the collet upsets 1525. The threaded portion 1670 is preferably adapted to be removably coupled to the second threaded portion 1645 of the second end 1625 of the outer collet support member 645. The threaded portion 1670 may include any number of conventional threaded portions. The threaded portion 1670 is preferably a stub acme thread available from Halliburton Energy Services in order to optimally
- 15 provide high tensile strength.
- 20

The second end 1655 of the liner hanger setting sleeve 650 preferably includes the interior shoulder 1672 and the threaded portion 1673. The threaded portion 1673 is preferably adapted to be coupled to conventional tubular members. In this manner tubular members are hung from the second end 1655 of the liner hanger setting sleeve 650. The threaded portion 1673 may be any number of conventional commercially available threaded portions. The threaded portion 1673 is preferably a stub acme thread available from Halliburton Energy Services in order to provide high tensile strength.

The crossover valve shear pins 655 are coupled to the second support member 515. The crossover valve shear pins 655 are releasably coupled to corresponding ones of the crossover valve members 520. The crossover valve shear pins 655 may include any number of conventional commercially available shear pins. The crossover valve 5 shear pins 655 are preferably ASTM B16 Brass H02 condition shear pins available from Halliburton Energy Services in order to optimally provide consistency.

The set screws 660 coupled to the liner hanger 595 and the outer collet support member 645. The set screws 660 may include any number of conventional commercially available set screws.

10 The collet retaining sleeve shear pins 665 are coupled to the collet mandrel 610. The collet retaining shear pins 665 are releasably coupled to the collet retaining sleeve 635. The collet retaining sleeve shear pins 665 may include any number of conventional commercially available shear pins. The collet retaining sleeve shear pins 665 are preferably ASTM B16 Brass H02 condition shear pins available from 15 Halliburton Energy Services in order to optimally provide consistent shear force values.

The first passage 670 is fluidically coupled to the second passages 675 and the secondary throat passage 695. The first passage 670 is preferably defined by the interior of the first support member 505. The first passage 670 is preferably adapted to convey fluidic materials such as, for example, drilling mud, cement, and/or lubricants.

20 The first passage 670 is adapted to convey fluidic materials at operating pressures and flow rates ranging from about 0 to 10,000 psi and 0 to 650 gallons/minute.

The second passages 675 are fluidically coupled to the first passage 670, the third passage 680, and the crossover valve chambers 685. The second passages 675 are preferably defined by a plurality of radial openings provided in the second end 1010 of 25 the first support member 505. The second passages 675 are preferably adapted to convey fluidic materials such as, for example, drilling mud, cement and/or lubricants. The second passages 675 are preferably adapted to convey fluidic materials at operating

pressures and flow rates ranging from about 0 to 10,000 psi and 0 to 650 gallons/minute.

The third passage 680 is fluidically coupled to the second passages 675 and the force multiplier supply passages 790. The third passage 680 is preferably defined by
5 the radial gap between the second end 1010 of the first support member 505 and the first end 1060 of the second support member 515. The third passage 680 is preferably adapted to convey fluidic materials such as, for example, drilling mud, cement, and/or lubricants. The third passage 680 is preferably adapted to convey fluidic materials at operating pressures and flow rates ranging from about 0 to 10,000 psi and 0 to 200
10 gallons/minute.

The crossover valve chambers 685 are fluidically coupled to the third passage 680, the corresponding inner crossover ports 705, the corresponding outer crossover ports 710, and the corresponding seventh passages 770. The crossover valve chambers 685 are preferably defined by axial passages provided in the second support member
15 515. The crossover valve chambers 685 are movably coupled to corresponding crossover valve members 520. The crossover valve chambers 685 preferably have a substantially constant circular cross-section.

During operation of the apparatus 500 preferably one end of one or more of the crossover valve chambers 685 is pressurized by fluidic materials injected into the third
20 passage 680. In this manner, the crossover valve shear pins 655 are sheared and the crossover valve members 520 are displaced. The displacement of the crossover valve members 520 causes the corresponding inner and outer crossover ports, 705 and 710, to be fluidically coupled. The crossover valve chambers 685 are preferably pressurized by closing the primary and/or the secondary throat passages, 690 and 695, using
25 conventional plugs or balls, and then injecting fluidic materials into the first, second and third passages 670, 675 and 680.

The primary throat passage 690 is fluidically coupled to the secondary throat passage 695 and the fourth passage 700. The primary throat passage 690 is preferably

defined by a transitional section of the interior of the second support member 515 in which the inside diameter transitions from a first inside diameter to a second, and smaller, inside diameter. The primary throat passage 690 is preferably adapted to receive and mate with a conventional ball or plug. In this manner, the first passage 670
5 optimally fluidically isolated from the fourth passage 700.

The secondary throat passage 695 is fluidically coupled to the first passage 670 and the primary throat passage 695. The secondary throat passage 695 is preferably defined by another transitional section of the interior of the second support member 515 in which the inside diameter transitions from a first inside diameter to a second, and smaller, inside diameter. The secondary throat passage 695 is preferably adapted to receive and mate with a conventional ball or plug. In this manner, the first passage 670
10 optimally fluidically isolated from the fourth passage 700.

The inside diameter of the primary throat passage 690 is preferably less than or equal to the inside diameter of the secondary throat passage 695. In this manner, if required, a primary plug or ball can be placed in the primary throat passage 690, and then a larger secondary plug or ball can be placed in the secondary throat passage 695. In this manner, the first passage 670 is optimally fluidically isolated from the fourth
15 passage 700.

The fourth passage 700 is fluidically coupled to the primary throat passage 690, the seventh passage 770, the force multiplier exhaust passages 725, the collet release ports 745, and the collet release throat passage 755. The fourth passage 700 is preferably defined by the interiors of the second support member 515, the force multiplier inner support member 530, the first coupling 545, the third support member 550, the second coupling 605, and the collet mandrel 610. The fourth passage 700 is
20 preferably adapted to convey fluidic materials such as, for example, drilling mud, cement, and/or lubricants. The fourth passage 700 is preferably adapted to convey fluidic materials at operating pressures and flow rates ranging from about 0 to 10,000 psi and 0 to 650 gallons/minute.
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The inner crossover ports 705 are fluidically coupled to the fourth passage 700 and the corresponding crossover valve chambers 685. The inner crossover ports 705 are preferably defined by substantially radial openings provided in an interior wall of the second support member 515. The inner crossover ports 705 are preferably adapted 5 to convey fluidic materials such as, for example, drilling mud, cement, and lubricants. The inner crossover ports 705 are preferably adapted to convey fluidic materials at operating pressures and flow rates ranging from about 0 to 10,000 psi and 0 to 50 gallons/minute.

During operation of the apparatus 500, preferably the inner crossover ports 705 10 are controllably fluidically coupled to the corresponding crossover valve chambers 685 and outer crossover ports 710 by displacement of the corresponding crossover valve members 520. In this manner, fluidic materials within the fourth passage 700 are exhausted to the exterior of the apparatus 500.

The outer crossover ports 710 are fluidically coupled to corresponding crossover 15 valve chambers 685 and the exterior of the apparatus 500. The outer crossover ports 710 are preferably defined by substantially radial openings provided in an exterior wall of the second support member 515. The outer crossover ports 710 are preferably adapted to convey fluidic materials such as, for example, drilling mud, cement, and lubricants. The outer crossover ports 710 are preferably adapted to convey fluidic 20 materials at operating pressures and flow rates ranging from about 0 to 10,000 psi and 0 to 50 gallons/minute.

During operation of the apparatus 500, preferably the outer crossover ports 710 25 are controllably fluidically coupled to the corresponding crossover valve chambers 685 and inner crossover ports 705 by displacement of the corresponding crossover valve members 520. In this manner, fluidic materials within the fourth passage 700 are exhausted to the exterior of the apparatus 500.

The force multiplier piston chamber 715 is fluidically coupled to the third passage 680. The force multiplier piston chamber 715 is preferably defined by the annular

region defined by the radial gap between the force multiplier inner support member 530 and the force multiplier outer support member 525 and the axial gap between the end of the second support member 515 and the end of the lubrication fitting 565.

- During operation of the apparatus, preferably the force multiplier piston chamber 715 is pressurized to operating pressures ranging from about 0 to 10,000 psi. The pressurization of the force multiplier piston chamber 715 preferably displaces the force multiplier piston 535 and the force multiplier sleeve 540. The displacement of the force multiplier piston 535 and the force multiplier sleeve 540 in turn preferably displaces the mandrel 580 and expansion cone 585. In this manner, the liner hanger 595 is radially expanded. The pressurization of the force multiplier piston chamber 715 preferably directly displaces the mandrel 580 and the expansion cone 585. In this manner, the force multiplier piston 535 and the force multiplier sleeve 540 may be omitted. The lubrication fitting 565 preferably further includes one or more slots 566 for facilitating the passage of pressurized fluids to act directly upon the mandrel 580 and expansion cone 585.

- The force multiplier exhaust chamber 720 is fluidically coupled to the force multiplier exhaust passages 725. The force multiplier exhaust chamber 720 is preferably defined by the annular region defined by the radial gap between the force multiplier inner support member 530 and the force multiplier sleeve 540 and the axial gap between the force multiplier piston 535 and the first coupling 545. During operation of the apparatus 500, preferably fluidic materials within the force multiplier exhaust chamber 720 are exhausted into the fourth passage 700 using the force multiplier exhaust passages 725. In this manner, during operation of the apparatus 500, the pressure differential across the force multiplier piston 535 is substantially equal to the difference in operating pressures between the force multiplier piston chamber 715 and the fourth passage 700.

The force multiplier exhaust passages 725 are fluidically coupled to the force multiplier exhaust chamber 720 and the fourth passage 700. The force multiplier

exhaust passages 725 are preferably defined by substantially radial openings provided in the second end 1160 of the force multiplier inner support member 530.

The second annular chamber 735 is fluidically coupled to the third annular chamber 750. The second annular chamber 735 is preferably defined by the annular region defined by the radial gap between the third support member 550 and the liner hanger 595 and the axial gap between the centralizer 590 and the collet assembly 625. During operation of the apparatus 500, preferably fluidic materials displaced by movement of the mandrel 580 and expansion cone 585 are conveyed from the second annular chamber 735 to the third annular chamber 750, the sixth passages 765, and the sixth passage 760. In this manner, the operation of the apparatus 500 is optimized.

The expansion cone travel indicator ports 740 are fluidically coupled to the fourth passage 700. The expansion cone travel indicator ports 740 are controllably fluidically coupled to the second annular chamber 735. The expansion cone travel indicator ports 740 are preferably defined by radial openings in the third support member 550. During operation of the apparatus 500, preferably the expansion cone travel indicator ports 740 are further controllably fluidically coupled to the force multiplier piston chamber 715 by displacement of the travel port sealing sleeve 600 caused by axial displacement of the mandrel 580 and expansion cone 585. In this manner, the completion of the radial expansion process is indicated by a pressure drop caused by fluidically coupling the force multiplier piston chamber 715 with the fourth passage 700.

The collet release ports 745 are fluidically coupled to the fourth passage 700 and the collet sleeve release chamber 805. The collet release ports 745 are controllably fluidically coupled to the second and third annular chambers, 735 and 750. The collet release ports 745 are defined by radial openings in the collet mandrel 610. During operation of the apparatus 500, preferably the collet release ports 745 are controllably pressurized by blocking the collet release throat passage 755 using a conventional ball or plug. The pressurization of the collet release throat passage 755 in turn pressurizes the collet sleeve release chamber 805. The pressure differential between the

pressurized collet sleeve release chamber 805 and the third annular chamber 750 then preferably shears the collet shear pins 665 and displaces the collet retaining sleeve 635 in the axial direction.

- The third annular chamber 750 is fluidically coupled to the second annular
- 5 chamber 735 and the sixth passages 765. The third annular chamber 750 is controllably fluidically coupled to the collet release ports 745. The third annular chamber 750 is preferably defined by the annular region defined by the radial gap between the collet mandrel 610 and the collet assembly 625 and the first end 1585 of the collet retaining adapter and the axial gap between the collet assembly 625 and the intermediate portion
- 10 1590 of the collet retaining adapter 640.

- The collet release throat passage 755 is fluidically coupled to the fourth passage 700 and the fifth passage 760. The collet release throat passage 755 is preferably defined by a transitional section of the interior of the collet mandrel 610 including a first inside diameter that transitions into a second smaller inside diameter. The collet
- 15 release throat passage 755 is preferably adapted to receive and mate with a conventional sealing plug or ball. In this manner, the fourth passage 700 is optimally fluidically isolated from the fifth passage 760. The maximum inside diameter of the collet release throat passage 755 is preferably less than or equal to the minimum inside diameters of the primary and secondary throat passages, 690 and 695.
- 20 During operation of the apparatus 500, preferably a conventional sealing plug or ball is placed in the collet release throat passage 755. The fourth passage 700 and the collet release ports 745 are then pressurized. The pressurization of the collet release throat passage 755 in turn pressurizes the collet sleeve release chamber 805. The pressure differential between the pressurized collet sleeve release chamber 805 and the
- 25 third annular chamber 750 then preferably shears the collet shear pins 665 and displaces the collet retaining sleeve 635 in the axial direction.

The fifth passage 760 is fluidically coupled to the collet release throat passage 755 and the sixth passages 765. The fifth passage 760 is preferably defined by the interior of the second end 1595 of the collet retaining adapter 640.

The sixth passages 765 are fluidically coupled to the fifth passage 760 and the
5 third annular chamber 750. The sixth passages 765 are preferably defined by approximately radial openings provided in the intermediate portion 1590 of the collet retaining adapter 640. During operation of the apparatus 500, preferably the sixth passages 765 fluidically couple the third annular passage 750 to the fifth passage 760. In this manner, fluidic materials displaced by axial movement of the mandrel 580 and
10 expansion cone 585 are exhausted to the fifth passage 760.

The seventh passages 770 are fluidically coupled to corresponding crossover valve chambers 685 and the fourth passage 700. The seventh passages 770 are preferably defined by radial openings in the intermediate portion 1065 of the second support member 515. During operation of the apparatus 700, the seventh passage 770
15 preferably maintain the rear portions of the corresponding crossover valve chamber 685 at the same operating pressure as the fourth passage 700. In this manner, the pressure differential across the crossover valve members 520 caused by blocking the primary and/or the secondary throat passages, 690 and 695, is optimally maintained.

The collet sleeve passages 775 are fluidically coupled to the second annular chamber 735 and the third annular chamber 750. The collet sleeve passages 775 are preferably adapted to convey fluidic materials between the second annular chamber 735 and the third annular chamber 750. The collet sleeve passages 735 are preferably defined by axial openings provided in the collet sleeve 635.
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The force multiplier supply passages 790 are fluidically coupled to the third passage 680 and the force multiplier piston chamber 715. The force multiplier supply passages 790 are preferably defined by a plurality of substantially axial openings in the second support member 515. During operation of the apparatus 500, the force
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multiplier supply passages 790 preferably convey pressurized fluidic materials from the third passage 680 to the force multiplier piston chamber 715.

- The first lubrication supply passage 795 is fluidically coupled to the lubrication fitting 1285 and the body of lubricant 575. The first lubrication supply passage 795 is 5 preferably defined by openings provided in the lubrication fitting 565 and the annular region defined by the radial gap between the lubrication fitting 565 and the mandrel 580. During operation of the apparatus 500, the first lubrication passage 795 is preferably adapted to convey lubricants from the lubrication fitting 1285 to the body of lubricant 575.
- 10 The second lubrication supply passage 800 is fluidically coupled to the body of lubricant 575 and the expansion cone 585. The second lubrication supply passage 800 is preferably defined by the annular region defined by the radial gap between the expansion mandrel 580 and the liner hanger 595. During operation of the apparatus 500, the second lubrication passage 800 is preferably adapted to convey lubricants from 15 the body of lubricant 575 to the expansion cone 585. In this manner, the dynamic interface between the expansion cone 585 and the liner hanger 595 is optimally lubricated.

- The collet sleeve release chamber 805 is fluidically coupled to the collet release ports 745. The collet sleeve release chamber 805 is preferably defined by the annular 20 region bounded by the recess 1455 and the second shoulder 1575. During operation of the apparatus 500, the collet sleeve release chamber 805 is preferably controllably pressurized. This manner, the collet release sleeve 635 is axially displaced.

- Referring to FIGS. 4A to 4G, during operation of the apparatus 500, the apparatus 500 is coupled to an annular support member 2000 having an internal passage 2001, a first coupling 2005 having an internal passage 2010, a second coupling 2015, a third coupling 2020 having an internal passage 2025, a fourth coupling 2030 having an 25 internal passage 2035, a tail wiper 2050 having an internal passage 2055, a lead wiper 2060 having an internal passage 2065, and one or more tubular members 2070.

The annular support member 2000 may include any number of conventional commercially available annular support members. The annular support member 2000 preferably further includes a conventional controllable vent passage for venting fluidic materials from the internal passage 2001. In this manner, during placement of the apparatus 500 in the wellbore 2000, fluidic materials in the internal passage 2001 are vented thereby minimizing surge pressures.

5 The first coupling 2005 is preferably removably coupled to the second threaded portion 1615 of the collet retaining adapter 640 and the second coupling 2015. The first coupling 2005 may comprise any number of conventional commercially available couplings. The first coupling 2005 is preferably an equalizer case available from Halliburton Energy Services in order to optimally provide containment of the equalizer valve.

10 The second coupling 2015 is preferably removably coupled to the first coupling 2005 and the third coupling 2020. The second coupling 2015 may comprise any number of conventional commercially available couplings. The second coupling 2015 is preferably a bearing housing available from Halliburton Energy Services in order to optimally provide containment of the bearings.

15 The third coupling 2020 is preferably removably coupled to the second coupling 2015 and the fourth coupling 2030. The third coupling 2020 may comprise any number of conventional commercially available couplings. The third coupling 2020 is preferably an SSR swivel mandrel available from Halliburton Energy Services in order to optimally provide for rotation of tubular members positioned above the SSR plug set.

20 The fourth coupling 2030 is preferably removably coupled to the third coupling 2020 and the tail wiper 2050. The fourth coupling 2030 may comprise any number of conventional commercially available couplings. The fourth coupling 2030 is preferably a lower connector available from Halliburton Energy Services in order to optimally provide a connection to a SSR plug set.

The tail wiper 2050 is preferably removably coupled to the fourth coupling 2030 and the lead wiper 2060. The tail wiper 2050 may comprise any number of conventional commercially available tail wipers. The tail wiper 2050 is preferably an SSR top plug available from Halliburton Energy Services in order to optimally provide separation of cement and drilling mud.

5 The lead wiper 2060 is preferably removably coupled to the tail wiper 2050. The lead wiper 2060 may comprise any number of conventional commercially available tail wipers. The lead wiper 2060 is preferably an SSR bottom plug available from Halliburton Energy Services in order to optimally provide separation of mud and cement.

10 The first coupling 2005, the second coupling 2015, the third coupling 2020, the fourth coupling 2030, the tail wiper 2050, and the lead wiper 2060 are preferably a conventional SSR wiper assembly available from Halliburton Energy Services in order to optimally provide separation of mud and cement.

15 The tubular member 2070 are coupled to the threaded portion 1673 of the liner hanger setting sleeve 650. The tubular member 2070 may include one or more tubular members. The tubular member 2070 preferably includes a plurality of conventional tubular members coupled end to end.

20 The apparatus 500 is then preferably positioned in a wellbore 2100 having a preexisting section of wellbore casing 2105 using the annular support member 2000. The wellbore 2100 and casing 2105 may be oriented in any direction from the vertical to the horizontal. The apparatus 500 is preferably positioned within the wellbore 2100 with the liner hanger 595 overlapping with at least a portion of the preexisting wellbore casing 2105. During placement of the apparatus 500 within the wellbore 2100, 25 preferably fluidic materials 2200 within the wellbore 2100 are conveyed through the internal passage 2065, the internal passage 2055, the internal passage 2035, the internal passage 2025, the internal passage 2010, the fifth passage 760, the collet release throat passage 755, the fourth passage 700, the primary throat passage 690, the secondary

- throat passage 695, the first passage 670, and the internal passage 2001. In this manner, surge pressures during insertion and placement of the apparatus 500 within the wellbore 2000 are minimized. The internal passage 2001 preferably further includes a controllable venting passage for conveying fluidic materials out of the internal passage
- 5 2001.
- Referring to FIGS. 5A to 5C, in the event of an emergency after placement of the apparatus 500 within the wellbore 2000, the liner hanger 595, the outer collet support member 645, and the liner hanger setting sleeve 650 are decoupled from the apparatus 500 by first placing a ball 2300 within the collet release throat passage 755.
- 10 A quantity of a fluidic material 2305 is then injected into the fourth passage 700, the collet release ports 745, and the collet sleeve release chamber 805. The fluidic material 2305 is preferably a non-hardenable fluidic material such as, for example, drilling mud. Continued injection of the fluidic material 2305 preferably pressurizes the collet sleeve release chamber 805. The collet sleeve release chamber 805 is preferably pressurized
- 15 to operating pressures ranging from about 1,000 to 3,000 psi in order to optimally provide a positive indication of the shifting of the collet retaining sleeve 635 as indicated by a sudden pressure drop. The pressurization of the collet sleeve release chamber 805 preferably applies an axial force to the collet retaining sleeve 635. The axial force applied to the collet retaining sleeve 635 preferably shears the collet
- 20 retaining sleeve shear pins 665. The collet retaining sleeve 635 then preferably is displaced in the axial direction 2310 away from the collet upsets 1525. The collet retaining sleeve 635 is preferably axially displaced when the operating pressure within the collet sleeve release chamber 805 is greater than about 1650 psi. In this manner, the collet upsets 1525 are no longer held in place within the collet slots 1600 and 1665 by
- 25 the collet retaining sleeve 635.

The collet mandrel 610 is preferably then displaced in the axial direction 2315 causing the collet upsets 1525 to be moved in a radial direction 2320 out of the collet slots 1665. The liner hanger 595, the outer collet support member 645, and the liner

- hanger setting sleeve 650 are thereby decoupled from the remaining portions of the apparatus 500. The remaining portions of the apparatus 500 are then removed from the wellbore 2100. In this manner, in the event of an emergency during operation of the apparatus, the liner hanger 595, the outer collet support member 645, and the liner
- 5 hanger setting sleeve 650 are decoupled from the apparatus 500. This provides an reliable and efficient method of recovering from an emergency situation such as, for example, where the liner hanger 595, and/or outer collet support member 645, and/or the liner hanger setting sleeve 650 become lodged within the wellbore 2100 and/or the wellbore casing 2105.
- 10 Referring to FIGS. 6A to 6C, after positioning the apparatus 500 within the wellbore 2100, the lead wiper 2060 is released from the apparatus 500 by injecting a conventional ball 2400 into an end portion of the lead wiper 2060 using a fluidic material 2405. The fluidic material 2405 is preferably a non-hardenable fluidic material such as, for example, drilling mud.
- 15 Referring to FIGS. 7A to 7G, after releasing the lead wiper 2060 from the apparatus 500, a quantity of a hardenable fluidic sealing material 2500 is injected from the apparatus 500 into the wellbore 2100 using the internal passage 2001, the first passage 670, the secondary throat passage 695, the primary throat passage 690, the fourth passage 700, the collet release throat passage 755, the fifth passage 760, the
- 20 internal passage 2010, the internal passage 2025, the internal passage 2035, and the internal passage 2055. The hardenable fluidic sealing material 2500 preferably substantially fills the annular space surrounding the liner hanger 595. The hardenable fluidic sealing material 2500 may include any number of conventional hardenable fluidic sealing materials such as, for example, cement or epoxy resin. The hardenable
- 25 fluidic sealing material preferably includes oil well cement available from Halliburton Energy Services in order to provide an optimal seal for the surrounding formations and structural support for the liner hanger 595 and tubular members 2070. The injection of the hardenable fluidic sealing material 2500 is preferably omitted.

- As illustrated in FIG. 7C, prior to the initiation of the radial expansion process, the preload spring 560 exerts a substantially constant axial force on the mandrel 580 and expansion cone 585. In this manner, the expansion cone 585 is maintained in a substantially stationary position prior to the initiation of the radial expansion process.
- 5 The amount of axial force exerted by the preload spring 560 is preferably varied by varying the length of the spring spacer 555. The axial force exerted by the preload spring 560 on the mandrel 580 and expansion cone 585 preferably ranges from about 500 to 2,000 lbf in order to optimally provide an axial preload force on the expansion cone 585 to ensure metal to metal contact between the outside diameter of the
- 10 expansion cone 585 and the interior surface of the liner hanger 595.

Referring to FIGS. 8A to 8C, after injecting the hardenable fluidic sealing material 2500 out of the apparatus 500 and into the wellbore 2100, the tail wiper 2050 is preferably released from the apparatus 500 by injecting a conventional wiper dart 2600 into the tail wiper 2050 using a fluidic material 2605. The fluidic material 2605 is 15 preferably a non-hardenable fluidic material such as, for example, drilling mud.

Referring to FIGS. 9A to 9H, after releasing the tail wiper 2050 from the apparatus 500, a conventional ball plug 2700 is placed in the primary throat passage 690 by injecting a fluidic material 2705 into the first passage 670. A conventional ball plug 2710 is preferably also placed in the secondary throat passage 695. In this 20 manner, the first passage 670 is optimally fluidically isolated from the fourth passage 700. The differential pressure across the ball plugs 2700 and/or 2710 preferably ranges from about 0 to 10,000 psi in order to optimally fluidically isolate the first passage 670 from the fourth passage 700. The fluidic material 2705 is preferably a non-hardenable fluidic material. The fluidic material 2705 preferably includes one or more of the 25 following: drilling mud, water, oil and lubricants.

The injected fluidic material 2705 preferably is conveyed to the crossover valve chamber 685 through the first passage 670, the second passages 675, and the third passage 680. The injected fluidic material 2705 is also preferably conveyed to the force

- multiplier piston chamber 715 through the first passage 670, the second passages 675, the third passage 680, and the force multiplier supply passages 790. The fluidic material 2705 injected into the crossover valve chambers 685 preferably applies an axial force on one end of the crossover valve members 520. The axial force applied to
- 5 the crossover valve members 520 by the injected fluidic material 2705 preferably shears the crossover valve shear pins 655. In this manner, one or more of the crossover valve members 520 are displaced in the axial direction thereby fluidically coupling the fourth passage 700, the inner crossover ports 705, the crossover valve chambers 685, the outer crossover ports 710, and the region outside of the apparatus 500. In this
- 10 manner, fluidic materials 2715 within the apparatus 500 are conveyed outside of the apparatus. The operating pressure of the fluidic material 2705 is preferably gradually increased after the placement of the sealing ball 2700 and/or the sealing ball 2710 in the primary throat passage 690 and/or the secondary throat passage 695 in order to minimize stress on the apparatus 500. The operating pressure required to displace the
- 15 crossover valve members 520 preferably ranges from about 500 to 3,000 psi in order to optimally prevent inadvertent or premature shifting the crossover valve members 520. The one or more of the crossover valve members 520 are preferably displaced when the operating pressure of the fluidic material 2705 is greater than or equal to about 1860 psi. The radial expansion of the liner hanger 595 preferably does not begin until one or
- 20 more of the crossover valve members 520 are displaced in the axial direction. In this manner, the operation of the apparatus 500 is precisely controlled. Furthermore, the outer crossover ports 710 include controllable variable orifices in order to control the flow rate of the fluidic materials conveyed outside of the apparatus 500. In this manner, the rate of the radial expansion process is optimally controlled.
- 25 After displacing one or more of the crossover valve members 520, preferably the operating pressure of the fluidic material 2705 is gradually increased until the radial expansion process begins. In an exemplary embodiment, the radial expansion process begins when the operating pressure of the fluidic material 2705 within the force

multiplier piston chamber 715 is greater than about 3200 psi. The operating pressure within the force multiplier piston chamber 715 preferably causes the force multiplier piston 535 to be displaced in the axial direction. The axial displacement of the force multiplier piston 535 preferably causes the force multiplier sleeve 540 to be displaced 5 in the axial direction. Fluidic materials 2720 within the force multiplier exhaust chamber 720 are then preferably exhausted into the fourth passage 700 through the force multiplier exhaust passages 725. In this manner, the differential pressure across the force multiplier piston 535 is maximized. In an exemplary embodiment, the force multiplier piston 535 includes about 11.65 square inches of surface area in order to 10 optimally increase the rate of radial expansion of the liner hanger 595 by the expansion cone 585. The operating pressure within the force multiplier piston chamber 715 preferably ranges from about 1,000 to 10,000 psi during the radial expansion process in order to optimally provide radial expansion of the liner hanger 595.

The axial displacement of the force multiplier sleeve 540 preferably causes the 15 force multiplier sleeve 540 to drive the mandrel 580 and expansion cone 585 in the axial direction. The axial displacement of the expansion cone 585 radially expands the liner hanger 595 into contact with the preexisting wellbore casing 2105. The operating pressure within the force multiplier piston chamber 715 preferably also drives the mandrel 580 and expansion cone 585 in the axial direction. In this manner, the axial 20 force for axially displacing the mandrel 580 and expansion cone 585 preferably includes the axial force applied by the force multiplier sleeve 540 and the axial force applied by the operating pressure within the force multiplier piston chamber 715. The force multiplier piston 535 and the force multiplier sleeve 540 are omitted and the mandrel 580 and expansion cone 585 are driven solely by fluid pressure.

25 The radial expansion of the liner hanger 595 preferably causes the top rings 1385 and the lower rings 1390 of the liner hanger 595 to penetrate the interior walls of the preexisting wellbore casing 2105. In this manner, the liner hanger 595 is optimally coupled to the wellbore casing 2105. During the radial expansion of the liner hanger

595, preferably the intermediate sealing members 1395 of the liner hanger 595 fluidically seal the interface between the radially expanded liner hanger 595 and the interior surface of the wellbore casing 2105.

- During the radial expansion process, the dynamic interface between the exterior surface of the expansion cone 585 and the interior surface of the liner hanger 595 is preferably lubricated by lubricants supplied from the body of lubricant 575 through the second lubrication supply passage 800. In this manner, the operational efficiency of the apparatus 500 during the radial expansion process is optimized. The lubricants supplied by the body of lubricant 575 through the second lubrication passage 800 are preferably injected into the dynamic interface between the exterior surface of the expansion cone 585 and the interior surface of the liner hanger 595 substantially as disclosed in one or more of the following: (1) U.S. Patent Application Serial No. 09/440,338, attorney docket number 25791.9.02, filed on 11/15/1999 now United States Patent 6,328,113, which claimed benefit of the filing date of U.S. Provisional Patent Application Serial Number 60/108,558, attorney docket number 25791.9, filed on 11/16/1998, (2) U.S. Patent Application Serial No. 09/454,139, attorney docket number 25791.3.02, filed on 12/31/1999 now United States Patent 6,497,289, which claimed benefit of the filing date of U.S. Provisional Patent Application Serial Number 60/111,293, filed on 12/7/1998, (3) U.S. Patent Application Serial Number 09/502,350, attorney docket number 25791.8.02, filed on 2/10/2000, which claimed the benefit of the filing date of U.S. Provisional Patent Application Serial Number 60/119,611, attorney docket number 25791.8, filed 2/11/1999, (4) U.S. Patent Application Serial Number 09/510,913, attorney docket number 25791.7.02, filed on 2/23/2000, which claimed the benefit of the filing date of U.S. Provisional Patent Application Serial Number 60/121,702, attorney docket number 25791.7, filed on 2/25/1999, (5) U.S. Patent Application Serial Number 09/511,941, attorney docket number 25791.16.02, filed on 2/24/2000 now United States Patent 6,575,240, which claimed the benefit of the filing date of U.S. Provisional Patent Application number 60/121,907, attorney

- docket number 25791.16, filed 2/26/1999, (6) U.S. Provisional Patent Application Serial Number 60/124,042, attorney docket number 25791.11, filed on 3/11/1999, (7) U.S. Provisional Patent Application Serial Number 60/131,106, attorney docket number 25791.23, filed on 4/26/1999, (8) U.S. Provisional Patent Application Serial Number 5 60/137,998, attorney docket number 25791.17, filed on 6/7/1999, (9) U.S. Provisional Patent Application Serial Number 60/143,039, attorney docket number 25791.26, filed on 7/9/1999, and (10) U.S. Provisional Patent Application Serial Number 60/146,203, attorney docket number 25791.25, filed on 7/29/1999, the disclosures of which are incorporated by reference.
- 10 The expansion cone 585 is reversible. In this manner, if one end of the expansion cone 585 becomes excessively worn, the apparatus 500 can be disassembled and the expansion cone 585 reversed in order to use the un-worn end of the expansion cone 585 to radially expand the liner hanger 595. The expansion cone 585 preferably further includes one or more surface inserts fabricated from materials such as, for 15 example, tungsten carbide, in order to provide an extremely durable material for contacting the interior surface of the liner hanger 595 during the radial expansion process.

During the radial expansion process, the centralizer 590 preferably centrally positions the mandrel 580 and the expansion cone 585 within the interior of the liner hanger 595. In this manner, the radial expansion process is optimally provided.

20 During the radial expansion process, fluidic materials 2725 within the second annular chamber 735 are preferably conveyed to the fifth passage 760 through the collet sleeve passages 775, the flow passages 1530, the third annular chamber 750, and the sixth passages 765. In this manner, the axial displacement of the mandrel 580 and the 25 expansion cone 585 are optimized.

Referring to FIGS. 10A to 10E, the radial expansion of the liner hanger 595 is stopped by fluidically coupling the force multiplier piston chamber 715 with the fourth passage 700. In particular, during the radial expansion process, the continued axial

displacement of the mandrel 580 and the expansion cone 585, caused by the injection of the fluidic material 2705, displaces the travel port sealing sleeve 600 and causes the force multiplier piston chamber 715 to be fluidically coupled to the fourth passage 700 through the expansion cone travel indicator ports 740. The travel port sealing sleeve 600 is preferably removably coupled to the third support member 550 by one or more shear pins. In this manner, accidental movement of the travel port sealing sleeve 600 is prevented.

The fluidic coupling of the force multiplier piston chamber 715 with the fourth passage 700 preferably reduces the operating pressure within the force multiplier piston chamber 715. The reduction in the operating pressure within the force multiplier piston chamber 715 preferably stops the axial displacement of the mandrel 580 and the expansion cone 585. In this manner, the radial expansion of the liner hanger 595 is optimally stopped. The drop in the operating pressure within the force multiplier piston chamber 715 is preferably remotely detected and the injection of the fluidic material 2705 is reduced and/or stopped in order to gradually reduce and/or stop the radial expansion process. In this manner, the radial expansion process is optimally controlled by sensing the operating pressure within the force multiplier piston chamber 715.

After the completion of the radial expansion process, the hardenable fluidic sealing material 2500 is preferably cured. In this manner, a hard annular outer layer of sealing material is formed in the annular region around the liner hanger 595. The hardenable fluidic sealing material 2500 is preferably omitted.

Referring to FIGS. 11A to 11E, the liner hanger 595, the outer collet support member 645, and the liner hanger setting sleeve 650 are then decoupled from the apparatus 500. The liner hanger 595, the collet retaining adapter 640, the outer collet support member 645, and the liner hanger setting sleeve 650 are preferably decoupled from the apparatus 500 by first displacing the annular support member 2000, the first support member 505, the second support member 515, the force multiplier outer support member 525, the force multiplier inner support member 530, the first coupling

545, the third support member 550, the second coupling 605, the collet mandrel 610, and the collet retaining adapter 640 in the axial direction 2800 relative to the liner hanger 595, the outer collet support member 645, and the liner hanger setting sleeve 650.

5 In particular, as illustrated in FIG. 11D, the axial displacement of the collet mandrel 610 in the axial direction 2800 preferably displaces the collet retaining sleeve 635 in the axial direction 2800 relative to the collet upsets 1525. In this manner, the collet upsets 1525 are no longer held in the collet slots 1665 by the collet retaining sleeve 635. Furthermore, the axial displacement of the collet mandrel 610 in the axial direction 2800 preferably displaces the first shoulder 1445 in the axial direction 2800 relative to the locking dogs 620. In this manner, the locking dogs 620 lock onto the first shoulder 1445 when the collet mandrel 610 is then displaced in the axial direction 2805. Axial displacement of the collet mandrel of about 1.50 inches preferably displaces the collet retaining sleeve 635 out from under the collet upsets 1525 and also 10 locks the locking dogs 620 onto the first shoulder 1445 of the collet mandrel 610. Furthermore, the axial displacement of the collet retaining adapter 640 in the axial direction 2800 also preferably displaces the slots 1600 away from the collet upsets 1525. 15

20 The liner hanger 595, the collet retaining adapter 640, the outer collet support member 645, and the liner hanger setting sleeve 650 are preferably then decoupled from the apparatus 500 by displacing the annular support member 2000, the first support member 505, the second support member 515, the force multiplier outer support member 525, the force multiplier inner support member 530, the first coupling 545, the third support member 550, the second coupling 605, the collet mandrel 610, and the collet retaining adapter 640 in the axial direction 2805 relative to the liner hanger 595, the outer collet support member 645, and the liner hanger setting sleeve 650. In particular, the subsequent axial displacement of the collet mandrel 610 in the axial direction 2805 preferably pulls and decouples the collet upsets 1525 from the 25

collet slots 1665. The angled outer surfaces 1545 of the collet upsets 1525 preferably facilitate the decoupling process.

If the locking dogs 620 do not lock onto the first shoulder 1445 of the collet mandrel 610, then the annular support member 2000, the first support member 505, the second support member 515, the force multiplier outer support member 525, the force multiplier inner support member 530, the first coupling 545, the third support member 550, the second coupling 605, the collet mandrel 610, and the collet retaining adapter 640 are then displaced back in the axial direction 2800 and rotated. The rotation of the annular support member 2000, the first support member 505, the second support member 515, the force multiplier outer support member 525, the force multiplier inner support member 530, the first coupling 545, the third support member 550, the second coupling 605, the collet mandrel 610, and the collet retaining adapter 640 preferably misaligns the collet slots 1600 and 1665. In this manner, a subsequent displacement of the in the axial direction 2805 pushes the collet upsets 1525 out of the collet slots 1665 in the liner hanger setting sleeve 650. The amount of rotation preferably ranges from about 5 to 40 degrees. In this manner, the liner hanger 595, the outer collet support member 645, and the liner hanger setting sleeve 650 are then decoupled from the apparatus 500.

The removal of the apparatus 500 from the interior of the radially expanded liner hanger 595 is preferably facilitated by the presence of the body of lubricant 575. In particular, the body of lubricant 575 preferably lubricates the interface between the interior surface of the radially expanded liner hanger 595 and the exterior surface of the expansion cone 585. In this manner, the axial force required to remove the apparatus 500 from the interior of the radially expanded liner hanger 595 is minimized.

Referring to FIGS. 12A to 12C, after the removal of the remaining portions of the apparatus 500, a new section of wellbore casing is provided that preferably includes the liner hanger 595, the outer collet support member 645, the liner hanger setting

sleeve 650, the tubular members 2070 and an outer annular layer of cured material 2900.

- The interior of the radially expanded liner hanger 595 is preferably used as a polished bore receptacle ("PBR"). The interior of the radially expanded liner hanger 595 is preferably machined and then used as a PBR. The first end 1350 of the liner hanger 595 is threaded and coupled to a PBR.

All surfaces of the apparatus 500 that provide a dynamic seal are preferably nickel plated in order to provide optimal wear resistance.

Referring to FIGS. 13A to 13G, an alternative embodiment of an apparatus 3000 for forming or repairing a wellbore casing, pipeline or structural support will be described. The apparatus 3000 preferably includes the first support member 505, the debris shield 510, the second support member 515, the one or more crossover valve members 520, the force multiplier outer support member 525, the force multiplier inner support member 530, the force multiplier piston 535, the force multiplier sleeve 540, the first coupling 545, the third support member 550, the spring spacer 555, the preload spring 560, the lubrication fitting 565, the lubrication packer sleeve 570, the body of lubricant 575, the mandrel 580, the expansion cone 585, the centralizer 590, the liner hanger 595, the travel port sealing sleeve 600, the second coupling 605, the collet mandrel 610, the load transfer sleeve 615, the one or more locking dogs 620, the locking dog retainer 622, the collet assembly 625, the collet retaining sleeve 635, the collet retaining adapter 640, the outer collet support member 645, the liner hanger setting sleeve 650, the one or more crossover valve shear pins 655, the one or more collet retaining sleeve shear pins 665, the first passage 670, the one or more second passages 675, the third passage 680, the one or more crossover valve chambers 685, the primary throat passage 690, the secondary throat passage 695, the fourth passage 700, the one or more inner crossover ports 705, the one or more outer crossover ports 710, the force multiplier piston chamber 715, the force multiplier exhaust chamber 720, the one or more force multiplier exhaust passages 725, the second annular chamber 735,

the one or more expansion cone travel indicator ports 740, the one or more collet release ports 745, the third annular chamber 750, the collet release throat passage 755, the fifth passage 760, the one or more sixth passages 765, the one or more seventh passages 770, the one or more collet sleeve passages 775, the one or more force multiplier supply passages 790, the first lubrication supply passage 795, the second lubrication supply passage 800, the collet sleeve release chamber 805, and a standoff adaptor 3005.

Except as described below, the design and operation of the first support member 505, the debris shield 510, the second support member 515, the one or more crossover valve members 520, the force multiplier outer support member 525, the force multiplier inner support member 530, the force multiplier piston 535, the force multiplier sleeve 540, the first coupling 545, the third support member 550, the spring spacer 555, the preload spring 560, the lubrication fitting 565, the lubrication packer sleeve 570, the body of lubricant 575, the mandrel 580, the expansion cone 585, the centralizer 590, the liner hanger 595, the travel port sealing sleeve 600, the second coupling 605, the collet mandrel 610, the load transfer sleeve 615, the one or more locking dogs 620, the locking dog retainer 622, the collet assembly 625, the collet retaining sleeve 635, the collet retaining adapter 640, the outer collet support member 645, the liner hanger setting sleeve 650, the one or more crossover valve shear pins 655, the one or more collet retaining sleeve shear pins 665, the first passage 670, the one or more second passages 675, the third passage 680, the one or more crossover valve chambers 685, the primary throat passage 690, the secondary throat passage 695, the fourth passage 700, the one or more inner crossover ports 705, the one or more outer crossover ports 710, the force multiplier piston chamber 715, the force multiplier exhaust chamber 720, the one or more force multiplier exhaust passages 725, the second annular chamber 735, the one or more expansion cone travel indicator ports 740, the one or more collet release ports 745, the third annular chamber 750, the collet release throat passage 755, the fifth passage 760, the one or more sixth passages 765, the one or more seventh

passages 770, the one or more collet sleeve passages 775, the one or more force multiplier supply passages 790, the first lubrication supply passage 795, the second lubrication supply passage 800, and the collet sleeve release chamber 805 of the apparatus 3000 are preferably provided as described above with reference to the apparatus 500 in FIGS. 2A to 12C.

5 Referring to FIGS. 13A to 13C, the standoff adaptor 3005 is coupled to the first end 1005 of the first support member 505. The standoff adaptor 3005 preferably has a substantially annular cross-section. The standoff adaptor 3005 may be fabricated from any number of conventional commercially available materials. The 10 standoff adaptor 3005 is fabricated from alloy steel having a minimum yield strength of about 75,000 to 140,000 psi in order to optimally provide high tensile strength and resistance to abrasion and fluid erosion. The standoff adaptor 3005 preferably includes a first end 3010, a second end 3015, an intermediate portion 3020, a first threaded portion 3025, one or more slots 3030, and a second threaded portion 3035.

15 The first end 3010 of the standoff adaptor 3005 preferably includes the first threaded portion 3025. The first threaded portion 3025 is preferably adapted to be removably coupled to a conventional tubular support member. The first threaded portion 3025 may be any number of conventional threaded portions. The first threaded portion 3025 is preferably a 4 ½" API IF JT BOX thread in order to optimally provide 20 tensile strength.

The intermediate portion 3020 of the standoff adaptor 3005 preferably includes the slots 3030. The outside diameter of the intermediate portion 3020 of the standoff adaptor 3005 is preferably greater than the outside diameter of the liner hanger 595 in order to optimally protect the sealing members 1395, and the top and bottom rings, 25 1380 and 1390, from abrasion when positioning and/or rotating the apparatus 3000 within a wellbore, or other tubular member. The intermediate portion 3020 of the standoff adaptor 3005 preferably includes a plurality of axial slots 3030 equally positioned about the circumference of the intermediate portion 3020 in order to

optimally permit wellbore fluids and other materials to be conveyed along the outside surface of the apparatus 3000.

The second end of the standoff adaptor 3005 preferably includes the second threaded portion 3035. The second threaded portion 3035 is preferably adapted to be 5 removably coupled to the first threaded portion 1015 of the first end 1005 of the first support member 505. The second threaded portion 3035 may be any number of conventional threaded portions. The second threaded portion 3035 is preferably a 4 1/2" API IF JT PIN thread in order to optimally provide tensile strength.

Referring to FIGS. 13D and 13E, in the apparatus 3000, the second end 1360 of 10 the liner hanger 595 is preferably coupled to the first end 1620 of the outer collet support member 645 using a threaded connection 3040. The threaded connection 3040 is preferably adapted to provide a threaded connection having a primary metal-to-metal seal 3045a and a secondary metal-to-metal seal 3045b in order to optimally provide a fluidic seal. The threaded connection 3040 is preferably a DS HST threaded 15 connection available from Halliburton Energy Services in order to optimally provide high tensile strength and a fluidic seal for high operating temperatures.

Referring to FIGS. 13D and 13F, in the apparatus 3000, the second end 1625 of the outer collet support member 645 is preferably coupled to the first end 1650 of the liner hanger setting sleeve 650 using a substantially permanent connection 3050. In 20 this manner, the tensile strength of the connection between the second end 1625 of the outer collet support member 645 and the first end 1650 of the liner hanger setting sleeve 650 is optimized. The permanent connection 3050 preferably includes a threaded connection 3055 and a welded connection 3060. In this manner, the tensile strength of the connection between the second end 1625 of the outer collet support 25 member 645 and the first end 1650 of the liner hanger setting sleeve 650 is optimized.

Referring to FIGS. 13D, 13E and 13F, in the apparatus 3000, the liner hanger setting sleeve 650 further preferably includes an intermediate portion 3065 having one or more axial slots 3070. The outside diameter of the intermediate portion 3065 of the

liner hanger setting sleeve 650 is preferably greater than the outside diameter of the liner hanger 595 in order to protect the sealing elements 1395 and the top and bottom rings, 1385 and 1390, from abrasion when positioning and/or rotating the apparatus 3000 within a wellbore casing or other tubular member. The intermediate portion 3065
5 of the liner hanger setting sleeve 650 preferably includes a plurality of axial slots 3070 equally positioned about the circumference of the intermediate portion 3065 in order to optimally permit wellbore fluids and other materials to be conveyed along the outside surface of the apparatus 3000.

The apparatus 500 and 3000 are preferably used to fabricate and/or repair a
10 wellbore casing, a pipeline, or a structural support. In several other alternative embodiments, the apparatus 500 and 3000 are used to fabricate a wellbore casing, pipeline, or structural support including a plurality of concentric tubular members coupled to a preexisting tubular member.

TABLE FOR CONVERSION TO METRIC UNITS

- 0 to 650 gallons/minute and 0 to 10,000 psi (0 to 2,460.51767 litres and 0 to 689.476 bar)
- 5 1000 to 10000 psi (68.95 to 689.5 bar)
75,000 to 140,000 psi (5,171.06796 to 9,652.660192 bar)
4 ½" (11.43 centimetres)
0.005 to 0.010 inches (0.0127 to 0.0254 centimetres)
500 to 2000 lbf/in (0.2394013 to 0.9576052 bar)
- 10 0.05 to 0.025 inches (0.127 to 0.0635 centimetres)
0.06 inches (0.1524 centimetres)
5 to 12 feet (1.524 metre to 3.6576 metre)
40,000 to 125,000 psi (5,171.06796 to 8,618.4466 bar)
0.12 to 2 inches (0.3048 to 5.08 centimetres)
- 15 8 to 20 inches (20.32 to 50.8 centimetres)
0.25 to 2 inches (0.635 to 5.08 centimetres)
0.10 to 2.00 inches (0.254 to 5.08 centimetres)
0 to 10,000 psi and 0 to 650 gallons/minute (0 to 689.476 bar and 0 to 2,460.51767 litres)
- 20 0 to 10,000 psi and 0 to 200 gallons/minute (0 to 689.476 bar and 0 to 757.08236 litres)
0 to 10,000 psi and 0 to 50 gallons/minute (0 to 689.476 bar and 0 to 189.27059 litres)
0 to 10,000 psi (0 to 689.476 bar)
1,000 to 3,000 psi (68.9475728 to 206.8427184 bar)
1650 psi (113.7634951 bar)
- 25 500 to 3,000 psi (34.4737864 to 206.8427184 bar)
3200 psi (220.632233 bar)

CLAIMS

1. An apparatus comprising:
 - an annular support member including a first passage;
 - 5 a manifold coupled to the annular support member, including:
 - a throat passage fluidically coupled to the first passage adapted to receive a fluid plug;
 - a second passage fluidically coupled to the throat passage;
 - 10 a third passage fluidically coupled to the first passage;
 - a fourth passage fluidically coupled to the third passage;
 - at least one valve chamber fluidically coupled to the fourth passage including corresponding movable valve elements;
 - one or more fifth passages fluidically coupled to the second passage and controllably coupled to said at least one valve chamber by corresponding movable valve elements;
 - 15 one or more sixth passages fluidically coupled to a region outside of the manifold and to corresponding valve chambers;
 - one or more seventh passages fluidically coupled to corresponding valve chambers and the second passage; and
 - 20 at least one force multiplier supply passage fluidically coupled to the fourth passage;
 - a force multiplier assembly coupled to the annular support member, including:
 - a force multiplier tubular member coupled to the manifold;
 - 25 an annular force multiplier piston chamber defined by the space between the annular support member and the force multiplier tubular member and fluidically coupled to the at least one force multiplier supply passage;

- an annular force multiplier piston positioned in the annular force multiplier piston chamber and movably coupled to the annular support member;
- 5 a force multiplier sleeve coupled to the annular force multiplier piston; a force multiplier sleeve sealing member coupled to the annular support member and movably coupled to the force multiplier sleeve for sealing the interface between the force multiplier sleeve and the annular support member;
- 10 an annular force multiplier exhaust chamber defined by the space between the annular force multiplier piston, the force multiplier sleeve, and the force multiplier sleeve sealing member; and a force multiplier exhaust passage fluidically coupled to the annular force multiplier exhaust chamber and the interior of the annular support member;
- 15 an expandable tubular member; a radial expansion assembly movably coupled to the annular support member, including:
- an annular mandrel positioned within the annular force multiplier piston chamber;
- 20 an annular expansion cone coupled to the annular mandrel and movably coupled to the expandable tubular member; a lubrication assembly coupled to the annular mandrel for supplying lubrication to the interface between the annular expansion cone and the expandable tubular member;
- 25 a centralizer coupled to the annular mandrel for centering the annular expansion cone within the expandable tubular member; and a preload assembly movably coupled to the annular support member for applying an axial force to the annular mandrel; and

- a coupling assembly coupled to the annular support member and releasably coupled to the expandable tubular member, including:
- 5 a tubular coupling member coupled to the expandable tubular member including one or more tubular coupling member slots;
- an annular support member coupling interface coupled to the annular support member including one or more annular support member coupling interface slots; and
- 10 a coupling device for releasably coupling the tubular coupling member to the annular support member coupling interface, including:
- 10 a coupling device body movably coupled to the annular support member;
- one or more resilient coupling device arms extending from the coupling device body; and
- 15 one or more coupling device coupling elements extending from corresponding coupling device arms adapted to removably mate with corresponding tubular coupling member and annular support member coupling slots.

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